SELECTIONS

FROM

THE RECORDS

OF

THE BENGAL GOVERNMENT.

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N°. XV.

PAPERS OF 1853 AND 1854

ON THE

DAMOODAH EMBANKMENTS,

&c, &c, &c

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DAMOODAH EMBANKMENTS,

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No 11145

FROM THE MILITARY BOARD,

TO THE HONORABLE J A DORIN,

Deputy Governor of Bengal,

REVENUE DEPARTMENT

Fort William, 16th January, 1854

HONORABLE SIR,

Department Public Works

IN continuation of our letter, No 10314, dated 4th February 1853, we have the honor to submit documents as per margin on the subject of the floods of the Damoodah River and the proposal to abandon the bunds on the right bank

Letter in original (with plans Nos 900 to 902 Embankments,) No 4005, dated 10th February, 1853 from Lieut Col Goodwyn, S E, S E P reporting on the state of the Damoodah Embankments and offering remarks on the proposed abandonment of the embankments on the right bank

Copy of letter, No 536, dated 25th May 1853 from the same with enclosure on the subject of the possibility of forming a cut from the Damoodah *via* the Buddye Nullah to the Dalkissore

Letter, (in original,) No 1473 dated 13th July, 1853, from the same, submitting Sketch Maps of Lieutenants Stewart and De Bourbel and Mr Neild's survey and levels of the country between the Damoodah and Roopnarain

Copy of the Survey Map with the calculated range of the floods marked thereon (plan No 962, Embankments)

Report in original of the Survey by Lieutenant De Bourbel

Drawings of Sections of the country compiled from the Survey (plans Nos 957 to 961 Embankments)

Sketch Map of the lower part of the Rivers Damoodah and Roopnarain and the adjacent country, showing the measures likely to be required for passing off the floods with safety to lower Mundleghaut (plan No 963 Embankments)

Memorandum in the Survey and question under discussion by Captain C H Dickens, Officiating Assistant Secretary, Military Board Office

2. The first of these documents, Lieutenant-Colonel Goodwyn's Inspection Report, we detained in our office, because it refers to the levels taken by Lieuts Stewart and De Bourbel, whose survey we were in daily expectation of receiving by the time the report had undergone consideration, and we thought it best to submit the whole of the papers on the subject at once.

3. Lieut.-Col. Goodwyn's Inspection Report is divided into three parts. The first describes the state of the embankments of the Damoo-

dah as he found them; namely, the bunds on the left bank in the Burdwan Division, generally in good condition and well raised, but some of the lines of the new embankments in the Superintending Engineer's opinion ill-placed, on the right bank the bunds neglected and in bad order, and in the Midnapore Division, no improvement since Lieut.-Col. Goodwyn last inspected the embankments The second part of the Report explains the Superintending Engineer's views on the subject of lining out new embankments, on the Establishment he considers necessary, on sluices, and on other points connected with the maintenance of the embankments in an efficient state The third part of the Report is that which more immediately concerns the question now under reference to Government In it the Superintending Engineer states his opinion of the feasibility of maintaining the bunds on both sides of the Damoodah and advises the contraction of the space allowed for the flow of the current where it appears to him to be too wide Lieut.-Col Goodwyn bases his conclusions on the known power of water to scour out and deepen the channel when it is contracted laterally, and refers to instances in which this mode of operation has effected great improvements in the channels of rivers, and to others in which the attempt to lower the flood level by allowing additional water-way has had injurious effects He refers to the features of the country as being unfavorable to the project of removing the bunds on the right bank of the Damoodah and deprecates any such measure, as unnecessary and fraught with ruinous consequences to the country

4 In his letter, No. 536, the Superintending Engineer, South-Eastern Provinces, in reply to the Board's letter desiring that the course of a branch of the Buddye Nullah might be traced towards the Dalkissore, with the view to a channel being formed to connect that river with the Damoodah, furnishes a Report from Lieut De Bourbel, stating that he had traced a Nullah from the Dalkissore to within 4½ miles of the nearest point of the Buddye, but that the intervening country was 100 feet on the average, above the bed of the Damoodah. Lieut. De Bourbel however observed that as the country further West was formed of detached hills, it was possible that by taking a somewhat longer course a more favorable line might be found, but he had been unable at that season to complete his survey or to take levels, for want of Establishment to clear away jungle We desired that the examination might be prosecuted next (the present) season.

5 In his subsequent letters, submitting the survey and Lieutenant De Bourbel's Report, Lieut.-Col Goodwyn remarks that no ridge of high land exists between the rivers for four-fifths of the distance included in the survey, and that the Dalkisore River is considerably lower than the Damoodah, and that the level of a very large tract of country, between the rivers, is considerably below the flood level of the Damoodah.* These circumstances Lieut-Col. Goodwyn refers to as confirmatory of the opinions expressed in his previous Report

6 It will be observed that Lieut-Col Goodwyn had not before him the complete survey when he wrote his Inspection Report, though he had at that time become aware of some of the results of the levelling operations, and it will further be seen that in submitting the Survey Map (which we had desired might be done without delay) he only detained it long enough to make a cursory examination, and kept no copy.

7. Finding that the levels of the survey showed the country between the rivers to have for the most part no decided features, and that it would be necessary to enter into long calculations to ascertain from the survey the probable range of the floods, the papers were made over to Captain C H Dickens, Assistant Secretary in our office, for this purpose. He has drawn up the accompanying memorandum detailing the modes and results of his calculation and the conclusions he has drawn from them in respect to the various projects for the improvement of the Damoodah.

8 Copies of this memorandum have, as already reported,* been sent to the Board of Revenue and to the Superintending Engineer South-Eastern Provinces The latter has been desired to furnish any further remarks he may have to make on the subject, for submission to Government

9 The main points of the conclusions drawn in this memorandum are, that the capacity of the Damoodah channel diminishes in so great a degree in passing from about 16 miles West of Burdwan to Omptah, that it cannot, when full up to the top of the bunds, carry off at the latter place one-eighth part of the flood discharge per second, which it may receive from the more capacious channel above, and that consequently the bunds cannot be maintained during any flood which may last longer than to fill the channel, which will be done by nine or ten hours of the heaviest flood discharge of water, that the declivity of the Damoodah

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* Military Board's Letter, No 10238, of 23rd December 1853.

is so great in passing over its sandy bed West of Burdwan, and so small in approaching Omptah, that the occurrence of heavy deposits of sand is inevitable; that consequently the river does not admit of improvement by closing its embankments, because sufficient velocity cannot be obtained by that means to carry away, in the lower parts of the river, all the sand received from above, so as to prevent a rise of the bed, much less to scour it out to such a degree as to make it contain and carry off the floods, that the attempt to form embankments enclosing a sufficiently wide channel to contain and carry off the floods, will be unsatisfactory and very costly; that to attempt to carry off the floods by a channel cut from the Damoodah into the Roopnaram, will be equally unsatisfactory and still more costly. Any complete and permanent measures for securing the country on both banks from inundation appearing to be impracticable, an examination is then made of the results of removing the bunds from the right bank, by which it appears, that though the country will be subjected to very heavy and violent floods, they will not be much more severe than those which have heretofore passed over the same tract, though more regular in occurrence, that the flood level of the river from about five miles West of Burdwan downwards will be reduced by from eight to four feet, rendering the bunds on the left bank comparatively safe, that to effect this, the bunds on the right need be removed only for 20 miles above the bend of the river, that the quantity of land liable to inundation in the highest floods will be 383 square miles (7,411,681 beegahs), but that a central bund may be constructed which will restrict the range of the floods to about 350 square miles (6,77,600 beegahs); that lower Mundelghaut cannot be protected as originally proposed by a cross bund at Omptah, but that it will be necessary to arrange the bunds so as to allow increased water-way for the floods to pass into the Roopnaram, which will probably require about 50,000 beegahs of land to be given up to the floods, that the state of things produced by these arrangements will probably not be permanent, and that the cost of the works will be a little more than 2½ lacs of rupees It is finally concluded that the removal of the bunds of the right bank, affording as it does almost complete security to the country on the left for a great part of the river's course, though not a final measure, is the best that can be adopted in the present state of things, and that if Government decide upon sanctioning it, estimates for the following works will be required.

(1) Re-arrangement of the bunds on the lower part of the course of the Roopnaraın to admit of the free passage of the floods, about 1½ lacs

(2) Construction of a central bund to limit the floods and mark the line separating the land, liable to inundation on the right bank of the Damoodah (Rupees 40,000).

(3.) Clearance of the bunds on the right bank of the Damoodah for about 20 miles from Sungutgola to the head of the Cana Nuddee (Rs. 50,000).

10. We have thought it best to submit the above memorandum entire along with Lieut.-Colonel Goodwyn's reports, only embodying abstracts of their contents in this letter, as the statements of facts and arguments brought forward in the discussion in question, cannot be compressed without losing force. We therefore beg to refer to the original documents for the full discussion of the question, and proceed now to make our remarks and recommendations based upon the information submitted, reserving our report on the Cana Nuddee dam (promised in our letter, No. 2916 of 12th July 1853), and on the retired embankment near it, on the subject of which we have received further communications from the Superintending Engineer, for a separate letter, which will be submitted at an early date.

11. The Officiating Chief Engineer cannot concur in all the conclusions drawn in Capt. Dickens's memorandum. He would in estimating the discharge of the river at Omptah have made some deduction on account of the tides which will be opposed to the floods 11 hours out of the 24, and though during the 13 hours of ebb the discharge of water will be accelerated, this will not prevent the check caused by the flood-tide from operating and causing a considerable rise in the flood level particularly with a strong South wind. Colonel Garstin thinks therefore that the inefficiency of the Damoodah channel has been somewhat under-rated. and he would also notice the effect of the waves, raised by a South wind with the ebb tide, in injuring the embankments, as another difficulty in maintaining them under such circumstances.

12. On the other hand the Officiating Chief Engineer thinks that the volume of the floods, and consequently their depth and velocity in passing over the country has been estimated too high. At least from what he has seen in the Patna and Behar districts, where the rivers are not bunded, Colonel Garstin is of opinion that the floods of the

unbunded river will be found very much less destructive than those caused by the bursting of bunds, within which the stream has been confined, and raised above the level of the country upon which it suddenly pours down.

13. The whole tenor of the memorandum, the Officiating Chief Engineer thinks, shows correctly that the system of bunds in this part of the country was a bad and mischievous one, and should never have been adopted. But the abolition of a vicious system which has been allowed to grow up and extend itself as this has done, is not so easy a matter, and many points must be considered and interests consulted before any change can be recommended It does not appear to the Officiating Chief Engineer that it would injure the Railway if the bunds were abolished on both banks of the Damoodah.

14 The Officiating Chief Engineer would advert to an instance in which the abolition of river bunds was carried out without injurious effects In 1821, the Burral River burst its bunds between Nattore and Beauleah, and Colonel Garstin was sent to report on the subject He recommended the abandonment of the bunds, and that large breaches should be cut at short distances to allow the water to flow freely over the country. This was done,* and the effects were that the villagers, knowing where and to what extent the next year's inundations would reach, were prepared against them, and no complaints were made or remission of revenue asked for, as far as Colonel Garstin knows In 1841 Colonel Garstin had an opportunity of examining the effect of the measure over a great extent of country, and found that large tracts had been raised, and in some places mulberry trees were growing where formerly rice grew The extent of the inundations of the Burral, the Officiating Chief Engineer thinks, was quite as great as that of the Damoodah, but the deposits contain less coarse sand than the floods of the Damoodah will probably carry over the country, being nearer to its source At any rate, the instance affords a good means of judging of the probable effects of abandoning bunds on the Damoodah

15 Taking the question as it now stands, the Officiating Chief Engineer considers it a choice of difficulties, but on mature consideration, he would recommend the abandonment of the bunds on the right bank of

* See Correspondence on the Rajshahye and Jessore bunds, Government letter, No. 392, dated 13th March 1832

the Damoodah as the best measure that can be adopted, there being no other attended with so few objections.

16. The Officiating Chief Engineer therefore solicits the orders of Government to direct the preparation of estimates proposed at the conclusion of the memorandum.

17. With reference to his colleague's remarks in the 22nd paragraph of this letter, the Officiating Chief Engineer cannot admit the correctness of the description of the Board's proceedings in the matter of the Cana Nuddee dam. The head of the nuddee was choked up by sand before the dam was constructed, the dam therefore cannot be said to have "blocked up" the channel, but was placed to arrest the water, in case, in high floods, it should rise over the bar of sand Nor can the Officiating Chief Engineer agree that the measure was "carried out, notwithstanding the earnest solicitation of the inhabitants of the district" through which the Cana Nuddee passes, for although fourteen of them did petition against the construction of the dam, one of the same parties and others had before, in petitioning for the opening of a canal, to carry the waters of the Damoodah into the Hooghly, represented the danger they were exposed to by the floods which the dam was constructed to arrest. The circumstances have been reported to Government in our letters, Nos. 5449 of 19th September, 1851, and 2916 of 12th July, 1853, and in conclusion the Officiating Chief Engineer would refer to the opinion expressed in his minute, copy of which was annexed to the former communication, that to cause the waters of the Damoodah to enter the Hooghly above Calcutta, would ruin the navigation of the latter river.

18. Lieut.-Col Mactier observes, that the question before the Board is, how the country can best be protected from the injurious effects of the annually recurring floods of the Damoodah Whether by embankments alone throughout its entire course, as suggested by the Superintending Engineer, South-Eastern Provinces, in his letter now submitted to Government, by the abandonment of these works on the right bank of the river, leaving the waters to spread and do their worst over the entire Districts lying between the Damoodah and the Dalkisore, or by a combined system of embankment and drainage.

19. If embankments could be so constructed as not to be liable to erosion, the Superintending Engineer's project might be feasible; but knowing as we do that the soil through which the course of this river passes is not of a quality to render this possible, Lieut.-Colonel

Mactier does not think the Superintending Engineer's plan can be recommended.

20. With regard to the abandonment of the bunds on the right bank originally suggested for the consideration of the Board by Lieutenant Beadle, adopted by the majority (Colonels Cheape and Hawkins), and advocated by Major Baker, the Government Consulting Engineer, it appears to Lieut.-Colonel Mactier that, unless it can be shown that injury to property would not be the consequence, or that Government is prepared to grant liberal compensation to parties whose property may be injured or destroyed by the measure, it cannot, with justice, be adopted.

21. Lieut.-Colonel Mactier would, therefore, instead of submerging 400 square miles of country, as proposed by his colleague, recommend that the bunds on both banks of the Damoodah be retired where the channel contracts, and constructed of efficient section as suggested in the 7th, 8th and 9th paras. of our Despatch, No. 5449 of 19th Sept. 1851; and with the view to retain the water as much as possible, and to avoid expenditure in increasing their dimensions, that advantage be taken of the natural outlets to lead off the surplus water into the Hooghly and Roopnarain.

22 The Cana Nuddee, one of these outlets, notwithstanding the earnest solicitation of the inhabitants of the district through which it passes, was blocked up during the dry season of 1852, by order of the majority of the Board,* so that not a drop of the surplus water passes that way Whether the Board had any right to obstruct this passage, Lieut-Col Mactier knows not, but, be this as it may, he would suggest to Government that the dam be removed, and the escape of the surplus water encouraged by the excavation of the channel, as prayed† for by the people, and recommended‡ by Major Kennedy, the late Consulting Engineer, and by the Stipendiary§ Member of the Military Board

23 With reference to the rough estimate of the cost of constructing a channel from the Damoodah to the Roopnarain, contained in Capt. Dickens's memorandum accompanying this letter, Lieut-Colonel

* *Vide* Military Board's letter to Government, No 2916, of 12th July, 1853

† *Vide* Government of Bengal's, No 898, of 16th November, 1848, to Military Board.

‡ *Vide* Government of Bengal's, No 552, of 6th May, 1851, to Military Board

§ *Vide* Colonel Mactier's Minute submitted to Government of Bengal with Military Board's letter, No 5950, of 17th October, 1851

Mactier would observe that he does not consider it necessary that the whole water-way should be excavated. With the fall allowed by the ground, he is of opinion that a deep and narrow channel, not more than one-tenth of the width of that estimated for, would suffice, as the action of the water would soon enlarge it to a sufficient degree.

24. Lieutenant Colonel Mactier would also advert to the probability of some shorter and less expensive line for the new channel being found higher up the Damoodah, where, though the land is generally high, there are intervening valleys and water-courses, by taking advantage of which a better line may be found. Lieutenant De Bourbel was ordered to examine the country last year, but the lateness of the season and the impracticable jungle prevented his completing survey.

25. This question, with others of equal importance, Lieut.-Colonel Mactier observes, may be taken up and reported upon by the Superintendent of Embankments, whose appointment has been recommended in our several letters as per margin, and who will be able to carry out whatever system may be determined on.

Board's letter No 2821 of 8th August, 1850
Ditto No 1692 of 11th June, 1853
Ditto No 2916 of 12th July, 1853, para 30th
Ditto No 3401 of 20th July, 1853, para 11th
Ditto No 7655 of 29th October, 1853, paras 65 and 66
Ditto No 10029 of 19th December, 1853, last para

We have the honor to be,

Honorable Sir,

Your most obedient Servants,

E. GARSTIN, *Colonel.*

W MACTIER, *Lieut.-Col*

No. 4005.

FROM LIEUT.-COL. H. GOODWYN,

Superintending Engineer, South-Eastern Provinces,

TO LIEUTENANT J. P. BEADLE,

Officiating Secretary, Military Board

Camp Luchunpore, Right Bank Damooda, 10*th February* 1853

SIR,

I HAVE the honor to submit the following Report on the River Damooda, embracing every subject connected with its embankments, bed, banks, drainage, and inundations, (having reference to your several letters as per margin) which subjects I have divided under three heads.

No 7637, 27th November 1852, and also to
No 4315, of 17th August 1852, and accompaniments, and
No 7557 of 24th November 1852.

1*st.* The actual state of the embankments themselves, nature of repairs, construction and present sections

2*nd.* Their alinement, protection by means of sloping of river bank, khall dams, sluices and drainage.

3*rd.* Retention, with reference to Major Baker's Report received with your No. 4315 of 17th August 1852, and your No 7557 of 24th November last.

There are many local minor details connected with the 1st Division, observed during the course of inspection, and may be supposed to rest between the Superintending Engineer and the Executive which would unnecessarily swell the report without affording information to the Board. They have been noted by the Superintending Engineer for reference on receipt of specifications or bills

BURDWAN DIVISION, LEFT BANK.—2. The embankments on left bank, commencing from about 4 miles to the westward of Gogaon

to Ragobpore, are continuous, with exception of two intervals at the villages of Nuldunga and Soodwar, which being on high spots at some distance from the river bank have not yet been touched by floods. This line has been entirely remodelled during last season, by being raised, slopes correspondingly carried out, sinnosities corrected, and in fact almost renewed, presenting a uniform and substantial appearance, the work having been carefully executed. Sections Nos. 1 to 4 on accompanying sheet, show their form and the flood height of last year, the highest for many years.

3. The bay at Ragobpore has already been reported on in my No. 3063 of 7th December last. Section No. 7 shows the nature of the embankments in the bay, and No 8 immediately opposite the dangerous bend in the "Banka" Nuddee, both are substantial, and being in a very exposed position have been increased considerably in strength. The bank of the river too has been well sloped off for the entire length of the bay. The strengthening of the embankments was completed before the rains, and as much of the river bank as could be sloped off during the rains, was so, the rest has been done since.

4. At Joojootee and from Belcoss to Beharpore new lines have been constructed previous to the last rains, No 5 Section showing the former, and No 6 the latter, they are excellent lines, and will most likely not require other than petty repairs for several years; there are three places where the inner slope borders on shallow tanks and the heel of the embankment requires to be protected by bamboo stakes and fascines, carrying the slope out a little further. This I have ordered to be done at once.

5. It was at Edilpore and Catgolah where several breaches had been made by the villagers during the rains, and reported on in my No. 1113 of 13th July 1852, these have all been strongly filled in, and the village of Catgolah removed entirely to within the embanked line. Sections Nos. 9, 10, 11 show an almost renewed line from Edilpore to Noutungaon or Sudder Ghât, in excellent order and completed during last season before the rains. Eastward of this spot the good work of straightening and strengthening is now in progress, (18th December 1852,) and where the direction of the present line does not require to be corrected, the Section is being increased on the inner slope only, the outer one being in good order, and thus retaining it firm on that side, at the same time avoiding the returfing of both slopes. Sections from Nos. 12 to 19 show the present state of the lines from Noutungaon to Hatsimul and that which it is intended they shall assume when completed.

6. From Catgolah, East of No. 19 to Humeerpoor, is a double row of large trees, the outer on the edge of the river bank; as the line of embankments is not very far from the river and the bank is corroding, it would prove a great preservative if these trees were cut ¾ through and allowed to fall over the river, still being retained to the bank by their roots, they must almost all inevitably be washed into the river this next rains, and I see no reason why they should not contribute to prevent the erosion of the bank, rather than be lost altogether. Between Catgolah and Chotepore the soil is loose and light, it is therefore necessary to make up by an increase of Section for want of density in the material, or a breach will be easily effected. At Hatsimul and a village beyond Chotepore eastward, the huts are close to the heel of the embankment, and the villagers have been in the habit of taking earth from the berm for the repair of their houses, a practice which, in addition to the various other evils, under which the Embankment Department labours, calls for remedial Regulations. Sections Nos 20, 21, 22.

7. At Debdah is a scene of desolation caused by a breach and inundation so far back as 21 years ago, from which the country has not yet recovered, sand and rank grass being all that is visible for three miles The embankment here is, as shown at Section No 23, being strengthened to the corresponding one in the same line, and continuing to Futtehpore.

8. From Futtehpore to Palerah the line (Sections 24, 25, 26,) is in good condition, but not sufficiently high, having only been 15" below the flood of last year It is being raised to the corresponding Sections to the above numbers, the embankment at Palnah is of such excellent soil that a slope of 2 to 1 is quite sufficient. Its extent is rather more than a mile, curves taken out and remodelled like the former ones. At eastern end of Palnah old line, is a new one in course of construction No. 27, the inner slope not requiring to be carried out to full extent; it meets the present line close to the western end of the great Solalpore new line, between which and the new Palnah one is a portion, Section (No 28) being strengthened and raised well beyond the flood level which it was not before. The cultivation here, as also at Futtehpore and between the two places, has been brought up to the very toe of the outer slope, for which there is no present remedy. This is a spot where the bank of the river may be sloped off with advantage, as the preservation of the embankment will be greatly enhanced thereby, and the soil is yielding.

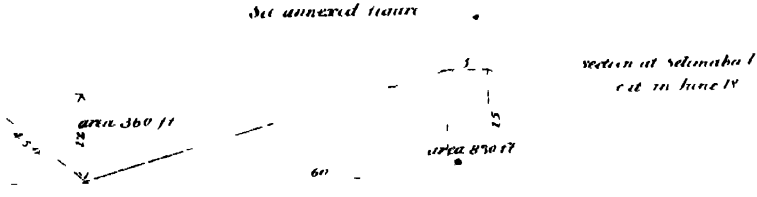
9. For a mile north of Solalpore commences a new line extending to the Canna Nuddee in rear of Selimabad, and entirely constructed before the rains last year. It is an exceedingly fine embankment, as regards its crest and slopes, but judgment has not been displayed in its direction, for though the shortest distance is a straight line between two points, and thereby the least amount of work has been obtained, yet there are other considerations which should be taken into account, and which render it advisable that embankments should follow, at moderate distance, and gentle curves, the course of the river. This line opposite the village of Dadpore, where the curve on the left bank is receding, is $1\frac{3}{4}$ miles from the bank, consequently much land is left unprotected, the embankment does not serve one of its most useful purposes, which in connection with the lines, on the right bank it ought to, *viz*, restrain the floods within such limits as shall force them to scour the bed of the river, moreover, the course of the reach south of Dadpore is thus at right angles with the embankment, a position which should never be permitted I am sorry to find that these principles have had no weight in more than one instance, and it is much to be regretted, for a slight increase in the length would have secured a comparatively permanent protection.

Had the dam of the Canna Nuddee been contemplated at the same time that this line North of it was laid out, the necessity of establishing that work nearer the mouth would have forced itself to the notice of all concerned, but having been hitherto left open, the idea of shutting it up did not, it appears, occur till the Board ordered it so late in the season as May last, when it was placed in continuation of the Selimabad line. The dam, though at that time necessarily in haste, has been exceedingly well-built, it is 30 feet wide at the crest, and the slopes are well carried out, the outer one being protected by bamboo piling. No small credit is due to the Executive Engineer and his Overseer, Sergeant McGuinness, for their exertions on this work, which, to, have made it what it is, in the short time allotted to its construction, must have been great. There is now a space of ground several beegahs in extent between the dam and river over which a deposit of fertile soil has been laid last season. This piece is now cultivated, but as it has become so by reason of the dam I submit the question of property for decision.

10. Accompanying this report is an accurate sketch of the village of Jamalpore and the several houses, enclosures and tanks which exist between the Canna Nuddee and Culnah. This I had very accurately

surveyed by Mr. Nield whilst on my inspection, in consequence of urgent entreaties on the part of the inhabitants that I would carry the embankment through the village, and they traced out a line for it which I have dotted. I went over the line with the people, and found that there were obstacles too serious to warrant an expenditure of money on the line. There is a dense plantation and some enclosures belonging to a temple close to the dam, there is also a dangerous hollow, branching from the right bank of Canna, which would lie at foot of the embankment, in addition to which the obstacles in the village itself are too numerous and serious to render the line practicable. The old embankment in front of the village is on the river bank and threatened, the bank itself being broken, and there being not space enough to slope it off. From the previous paragraph it may be observed that I am averse to a line so retired as the one (in yellow) projected at this spot, and it was partly for this reason, which tallied with the wishes of the zemindars that made me so minutely examine the spot in hopes of finding the means of approaching the embankment to the river, but found none. The correct principle for observance in laying out embankments is to afford as much protection to the country in general as a scientific arrangement will permit, and it must of course happen in some instances that a few suffer for the greater benefit of the many and this is one. The inner line is necessary as the only one which can be taken for the protection of the country behind it, and the point is a critical one, for from the expansion of the waters, the bed is on a high level, the floods are therefore high, and last season breached the line below the brick-built bazar, other breaches were also formed, but I am almost sure they were cut. If the villagers are anxious to do all they can to protect themselves, there is a measure open to them individually which I should not have felt justified in proposing as a permanent public arrangement. It is to give up part of the village on the banks and run a line at 1,000 feet from the present one, and continuing it up the bank of the Canna. The first part of the work might answer if they would give up the ground, but a glance at the sketch will show that the line along the Canna, would not only be expensive but weak, as its direction is at right angles to the torrent, and it would also be exposed to a destructive back water, on the reflux from the dam; besides, it would necessarily be seated on that hollow which has before been mentioned, so that its base would be precarious. I see no other course under the circumstances that could as a permanent public measure have been adopted, and

I will here state a firm conviction, that these lines, as well as the dam are quite strong enough to resist the floods of the Damoodah, tested as they have been by the actual weight of the material as opposed to that of flood-driven water. The water may be taken as weighing 65lbs. per cubic foot and the force exercised by a gale of wind is computed at 35lbs. per foot, which may also be said to be the maximum of a flood when swollen. Thus 100lbs. is the pressure on every foot of the embankment slope exerted at an angle of 45°, and as the rear slope of the Section of the embankment is more extended than 45°, the area of Section of the embankment somewhat exceeds that of the water pressing against it. The weight of the materials of which these embankments are made is fully 148lbs. per cubic foot consolidated, so that there is considerably more weight in the resisting mass, the Section being greater than in the pressing water, and this pressure can only last during a flood or storm. There is in fact an area of 360 feet of water at 100lbs. = 36,000lbs. to be resisted by a Section of 830 feet of material at 148lbs. = 1,22,840lbs. nearly four times the quantity.



I have gone into this detail to show that, having height sufficient, these embankments will not naturally give way under flood pressure, and as I have seen them under construction, I can vouch for their solidity. Should therefore breaches occur, as they did last year, and one serious one in even the Selimabad line, there can be little doubt but their origin will be in the acts of the villagers or zemindars; and situated as these two villages of Selimabad and Jumalpore are, with others of smaller note, it becomes almost necessary as a precautionary measure by every means to guard against the loss of money on the part of Government and life and property on the part of the inhabitants within the embankments: those means I have so often referred to that I will not recapitulate them here, as they may be in force before this report is submitted.

11. Between Culnah and Debdara a new inner line has been constructed as per Sections Nos. 29 to 33, and No. 34 is a portion of the old line against which the new one abuts, and which has been strengthened to assimilate with it, though it would have been better to have continued the new line round the village (as dotted) following a parallel course with the river, for the point of junction now has the direct action of the reach of the river against it at 80 feet from river, which was breached last year to the extent of 140 yards. It will be observed that from this point another new line takes off extending South of Bistopore, so that it is necessary to make this point at Debdara as strong as possible this year and provide for an inner line as (dotted) next. Fascines must be employed in renewing the outer face of the Section, and a report on it must be made directly after the rains

From Debdara southward to below Bistopore is a new line which, with the one last stated, was completed before the rains of 1852, the Sections Nos 35 to 37 show the construction. There are no less than four breaches on this line, the lower one of which is a very serious one. The river has cut into its bank, and a nullah 13 feet deep now runs through the embankment which however shallows to 5 at 800 feet in land. The water poured with great violence through this opening and reached the level of the floor of the bungalow at Serampore, 14 miles below it. There are two causes to which these breaches are attributable, one is that the earth-work was not completed till the month of June after rain had fallen, and was not enough consolidated before it had to bear the brunt of the stream, with turfing the roots of which had not struck, and with the old line in ruins. The second cause is the imperfect alinement before remarked on, the course of the stream bearing direct on to the points breached. The smaller breaches can be well filled in and made strong, but a new line must be formed round the lower and most formidable one, better adapted to the curve of the river and crossing the newly-formed nullah at a point where its depth is trifling. It will be necessary to dam up this nullah for some distance in front of new Section forming a berm, which must be protected by stakes. The bank of the river may here also be improved by cutting off its high edge, the earth from which will go into the nullah. Sections 38 to 40 show the breached line.

12. A small portion of the old line intervenes between the great breach above and a new line taking off from Mohunpore, which portion has been brought up to Section No. 40. Hence is a new line to Banga-

mara, to which there is the objection of its being too retired, leaving much land exposed, but in this instance it is not affected by the direct action of any reach of the river, and yet it has been breached in three different places, as marked. This portion was constructed during the first month of the rainy season, and hence its weakness, and its not having been brought up to its proper height for the crest is two feet lower than it should be as shown by flood-marks, owing to the haste with which it was constructed. These two lines mentioned in this and the last para. will prove with reference to the Military Board's letter, No 7309, of 9th November, and the 3rd para of No. 7637, of 27th idem, however willing I am to view the system as they direct, still, that works constructed during the rains do not afford protection to the country, and that in every instance in the Burdwan Division these lines have proved the most efficient that were completed before the rains where time and attention could be bestowed, and I with deference submit that it would be better to confine the work to strengthening even old lines than run the risk of new ones being imperfectly and weakly constructed, as these have been This line must be raised 2½ feet and the outer slope carried well out, for the stream from the breach above Mohunpore flowed down in front of the slope of this, and has formed a continuous channel, and which in prosecution of the work on the embankment itself I have directed to be cross dammed at every 100 yards, Sections Nos 41 to 45 were taken at intervals along this line.

13. At Bangamara the country in rear of the embankments is now causing the old line, against which the new one mentioned in last para. abuts, to assume a Section, No 46, the inner height of which is 18 feet, but the Section decreases again at Jeyrah This portion however is at present weak in comparison, it requires the crest to be extended to a width of 5 feet and the outer slope to a proportion of 4 to 1, leaving the inner slope as it is, for the soil is good, and its present base sufficient, and has been in existence upwards of 20 years (*vide* para. 10). Cultivation is here up to toe of outer slope.

14. From below Jeyrah to Mohunbattee is a new line constructed last season, a good and judicious one, but the excavations have been made continuous. I have directed the outer line to be dammed up as before at intervals, and the flood water may then safely be admitted to silt up the hollows. The lower end of this line joins the termination of the old zigzag bank which ends here entirely, the ground being high. It is not

so high however, as to warrant this gap when all else is cared for, and as a level lately taken has proved, the ground is covered with hollows through which floods have made their way. A line of small Section would answer, connecting the levels of what the crests of the lines North and South of this gap will be when complete.

15. From North of Cool Tigree to Chuckissab there is nothing but an insignificant and inefficient line, which, for no reason that I can discover, has been allowed to fall into ruin. The course meanders about through broken ground, and they are so utterly useless and from their position irreparable that an entire new line is necessary; from below the last named village the line somewhat improves, but the Section is bad, the level of the crest differs at every hundred feet, the slopes are much broken, and the line is tortuous, occasionally approaching dangerously near the river. In continuation of the line from Nussipore therefore a continuous new alinement must be formed, as per dotted line terminating at Nuskerpore.

16. Between Nuskerpore and Champadanga is an old line of small Section (No 47) which has not been repaired for four years, its crest is but three feet, and slopes weak, it is now being straightened and strengthened to the corresponding Section in same line. It is not very far from the river, in some places 150 feet, but the bank has been well sloped off, and I am sanguine as to the prevention of further cutting, for here, as also at Pospore lower down, a salient portion of the bank that the river was eating into was sloped off as far as was practicable in the interval between two floods, and the effect has been that of effectually stopping further dilapidation of the bank. This year the slopes will be turfed.

17. From below Champadanga to Comarchuck a new line was constructed before last rains, but it has been carried through low ground and, from the absence of a flood register, the crest is yet two feet lower than the level of last season proved that it ought to be, it has not been injured save the spoiling of 5,000 superficial feet of turfing, and it owes its safety probably to its distance from the river and the many intervening enclosures between it and the old broken line. Yet it would have been more generally serviceable if it had been half a mile nearer, and included within preservative limits more land. Its present Section is (Nos. 48 to 50) to be raised two feet, and in the lowest grounds even three feet, an endeavour also must be made to drain the marsh in which a portion of it stands, as there must exist an attractive communication between the water on both sides, rendering its stool any thing but firm.

18. At Comarchuck but a small portion of old line remains which will be brought up to Section No. 51 as far as Moroll, from whence little more than a mile of new line is now in course of construction (Section No. 52), the old one being very much dilapidated and very tortuous. The work is commenced and the Overseer and coolies gradually getting into the way of the new system of consolidation by formation of the Section in regular layers and treading each well down as the work proceeds.

The old line to Bodoorchuck is in very good order requiring no alteration.

19. A line commences at this point which was completed last year and is similar in nature and direction to that now being formed and noted in last para., but owing to the level of the flood not having been noted before, or that of last year having been unusually high, this portion requires to be raised two feet, Section No. 52. At the conclusion of this 1st part will be given an account of a guage and remedy I have instituted for this irregular practice of working in the dark, for a line constructed one year should in every respect be as perfect as circumstances will admit of, and sufficient height especially attended to, for the slight additions made to a tolerably good Section do not so well incorporate with the old work as to be so strong as if the whole had been correct at first. Besides there is double turfing.

20. At Binderman Chuck and Roimpore the banks of the river are partly sloped and may with considerable advantage be continued to a further extent, as it will certainly tend to their preservation and consequently that of the embankment above; an ugly re-entering angle is being corrected at the latter village, and the whole line from Hurriarpore to the Camarea Khal has within the last two years been remodelled by taking out the curves, and strengthening the Sections as shown Nos 53 to 55, the principal part, or that from below suite having been done before last rains. The bank of the river below Pospore has been sloped off (*vide* Remarks in para. 16) with very good effect.

21. The embankment has an abrupt termination quarter mile north of the Camarea Khal, which is merely an outlet from the Damoodah falling into the Mundorea at the distance of two miles to the eastward, it thus withdraws injuriously a portion of the flood waters of the Damoodah which here, as at the Canna has consequently become the repository of silt from the effects of diminished velocity. The same necessity that existed for damming the Canna is evident in the case of the Camarea,

and I have accordingly directed a dam to be constructed, nor is a sluice here requisite, for the course of the drainage is eastward and consequently carried off by the proximity of the Mundorea. There will soon be a silting up of this khal and the embankments on the South of its course may be abandoned. The line must be continued over the present above-mentioned interval northward along the left bank of the Damoodah

22. The embankments below this point assume quite a different aspect and the same amount of importance does not seem to have been allowed to them, or an equal amount of care bestowed on them as on the lines North of the Camarea, though the cause I know not unless it be from a reason which will be presently given. Below Govinchuck is a jheel on both sides of the embankment and percolation by attraction has taken place, so that the outer slope has subsided, both slopes must be carried out further and the toe and heel protected by stakes. Attempt must be made to drain this jheel into the river and iron pipe with valve run through the embankment to draw of the interior water, which seriously affects the stability of the bank.

23. From Niachuck to Cullunchuck is a line in rather a precarious position but which by close attention to the bank of the river I am sanguine of preserving, and if successful this season they may last many. Here also as at Pospore a portion of the bank into which the river had eaten was preserved by sloping during the rains Nos. 56, 57, show the Sections here, they are to be strengthened, the bank of the river is to be well sloped off and turfed and a berm formed from toe of outer slope of embankment to edge of river bank, filling all hollows There are three huts on the inner slope which must be purchased and the embankment kept free of such encumbrances. Below Cullunchuck the line is further from the river bank, was staightened and repaired last year, (No. 58) but below this part, at Singchuck, the position is similar to that at Niachuck (No 56) and similar means will be undertaken for its preservation and improvement.

24. From Singchuck to the junction of the Mundorea Khal the embankments may be said barely to exist, and a misapprehension appears to have been entertained regarding the portion of the line from Bhojan to the Mundorea in consequence of a representation by Lieutenant Colonel Sage in the 51st and 52nd paras. of his Report, No. 86, of 7th May 1849, in which he recommended the re-abolition of the embankments " from the " point opposite Comarchuck on right bank of Camarea along the same

" bank of Mundorea to its junction with the Damoodah." The idea entertained by both the Executive Engineer and Overseer is that the line of embankment on the Damoodah at this part was also abolished, and hence the ruinous state in which they are. The "induction" drawn by Lieut.-Col. Sage that the crops were ruined by the water is incorrect, for the baroo dhan requires almost a jheel to be grown in, and I found the country flooded in all those parts where they were preparing for this crop. But there is no reason why villages, cattle and other property should be destroyed to produce this crop, since all the water they require can be obtained by sluices from the Damoodah, and when no longer required for cultivation allowed to fall into the Mundorea by proper channels, which it would readily do, the Domoodah being on a higher level The embankments on the Damoodah require to be kept up most strictly, as not only the means of protecting the country from present inundation, but by forcing the floods to improve the river, prevent the woful effects of future years, should the bed from want of proper precaution, be raised. Complaints have been several times made from the inhabitants of the island formed by the three streams against the effects of the Damoodah waters, and on very just grounds, I therefore deem it of great importance that this line from Singchuck to the Mundorea Khal be entirely remodelled, for even the portion that exists is so inextricably woven amongst houses, trees, and tanks, as to defy correction or repair, with any chance of benefit. It is moreover necessary that the Civil Authority visit the spot in company with the Executive Engineer for the purpose of making over at once the land required for the new line (which I have dotted in the map as showing its general course) for it would take half a season to survey and measure the parcels appertaining to different owners, and much valuable time will be lost.

25. Still further to improve the protection and obtain the fullest amount of benefit from a perfected line, that portion of embankment from Burra Moira on left bank of the Mundorea to the bungalow below Omptah should be straightened and remodelled as I have shown on the map.

26. Omptah is the limit of the effects of the tides, and where the river quite changes its nature. For whereas above this point its bed is pure sand, from hence to the outfall at the Hooghly it is silt brought by the tidal waters which are impregnated with the alluvial soil through which the tributaries drain the valley. Above this point there is no drainage into the Damoodah owing to the high level of the tract through

which it flows, but below this, it receives through numerous muddy khals the drainage of the low lands contiguous to the Hooghly. I shall have more to say on this subject in Part III. of this Report.

27. From above Omptah to Doura the line was strengthened and repaired before the rains last year and is in excellent order, and between Doura and Rannapara the same operation is being carried on this year (Sections Nos. 59, 60). Below Rannapara a breach took place last rains at a sluice which was blown up owing to its faulty construction, the embankment has been greatly injured on both sides of it, and a channel formed to the river. This however can be strongly dammed and will silt up, and a new and better sluice provided. The line requires strengthening and its sinuosities corrected as far as a mile below Oudaon (Nos. 61, 62).

28. At Corda commences the depôt of the Bengal Coal Company, which straggles along the bank of the river outside the embankment as far as Futtehpore. They have gardens and jungle and hedges close to the outer slope of the embankment which greatly interferes with the necessary duty of the Department in keeping strict watch over the state of the embankments, and I bring this prominently to notice that measures may be taken to have the embankments kept clear of obstacles and encumbrances. At Futtehpore there is quarter mile of bazar, through which the crest of the embankment runs, the shops occupying both slopes, and there are such serious impediments to the formation of a new line within that, as the bank of the river is very high and solid, the arrangement must for the present be allowed to exist, (being safe) but the Establishment must carefully watch the spot to see that neither the river bank nor spaces between the shops are weakened by the abstraction of soil, or the bazar must be abandoned.

29. From Noupara to Musraka the state of the embankments is just as I left them at the period of my last inspection (1847) with the exception of two spots of an aggregate length of 2,000 feet (Section No. 63). The alinement is tortuous, the crests vary in height, the slopes are rugged and turfless, and the height is inefficient. The improvements demanded are, correction of the course as shown by the dotted line, the height to be increased two and half feet, the crest made five feet wide; and as the clay is here very strong and tenacious the outer slope need not be more than 3 to 1 and the inner 2 to 1 well turfed (Sections Nos. 64, 65). At Kalkapore is a small inlet which should be dammed near

the mouth, and a sluice set in it for drainage with a single opening of four or five feet.

The Musraka Khal will be reported on in connection with the road from Midnapore to Oolobariah.

BURDWAN DIVISION RIGHT BANK.—30. I will here report on the right bank as far as they extend through the Burdwan Division, for there is a hiatus from just above the Camarea Khal, and the embankments in the Midnapore Division, are of a nature peculiar to themselves, at least as far as I have yet observed on this river. The right bank lines have not been attended to save in a few spots at the lower parts of the river's course, as there seems to have been a demur regarding their retention, pending the solution of the question of how the inundating waters of the Damoodah are to be disposed of in the event of their abolition. In Part III. of this Report I hope to be able to bring forward such arguments in favor of their retention as shall, I earnestly hope, prove that the greatest advantages are to be reaped by keeping the floods to the duty which Nature has assigned to them, *viz*, of flowing in their prescribed channel.

The right bank lines commence opposite to Gogaon, those on the Damoodah at that point and between that and Burdwan being at intervals only, as regards the Government charge, portions being in the hands of zemindars.

Those on the "Buddye" Nullah alone have received any repairs for some years.

As far down as Cholbolpore on the Damoodah, they are very inferior in Section as shown by (Nos. 96 to 99), have been breached in several places, badly lined out, and quite inefficient.

31. A line of the very worst kind (zemindaree) intervenes between Cholbolpore and Comarpore below which to Kistopore is an indifferent low Section, when suddenly it increases to that at (No. 100) varying in height from 12 to 14 feet (Nos. 101, 102,) but diminishing to No. 103 at Sikarpore. The floods have overtopped the lines of small Section noted above, rushed to a lower level formed by excavations and jheels, and formed deep channels under the inner slopes of the larger lines, undermining them, so that even at Sadeepore where the Section is strongest it has been breached for distances varying from 50 to 1,500 feet. The villagers seem to have obtained possession of these embankments, they cut the turf, picket their cattle on the slopes and at Seekistopore were actually making bricks at the foot of the outer slopes.

32. From Sikarpore to Jotechund the Sections are various as shown from Nos. 104 to 120, but worse in appearance and position than can be shown by Section or Map. Tanks and jheels formed by breaches exist at the feet of both slopes, and visible percolation taking place through the Sections.

The difference in the appearance of the crops and country on this side where devastation has been caused by floods is great and marked, and would doubtless have been more ruinous but for the rapid fall of the country towards the West, which will be noticed hereafter.

33. At Jotechund is a zemindaree line in ruins, and below that point the neglected Sections of the Government lines pursue a course composed of every variety of curve, so crooked that they are double the extent they need be if properly laid out, rugged and breached in several places. Between Sialee and Bangamara I observed a better line in better order, perhaps preserved by the river bank which is here very high.

34. At Poorsoora some repairs were in progress improving the alinement and strengthening, but I stopped the work, pending a reply to my No. 3243 of 22nd December last, para 7. For new lines, and even improvements to old ones can only be properly regulated in connexion with a complete protective bank, the height of which will best be ascertained by levels now being taken from left bank to right, should those on the right be retained

35. Below Hailanchuck there are some better lines and less crooked in their trace than those above, they are weak though and in many places require complete renewal, particularly in the neighbourhood of Boolsoot and Kuttulpore, but for the reason in last para. their repairs must be held in abeyance.

36. At Golah Coorchee is the offset of the Damoodah Khal from which branches almost immediately the Gojah Khal, thus abstracting a large quantity of flood water from their legitimate duty. If the embankment on the right bank are retained, this outlet must necessarily be dammed strongly. The effects of its existence are visible on the map. The breadth of the Damoodah is much encreased, the power of its current much weakened, and sand is deposited. This will be scoured and improved when the protection is equal on both banks, and then only.

37. Beyond is a straggling, irregular inefficient line for about two miles lower, and a small embankment on left bank of Damoodah Khal rather longer than the form but in bad condition. There do not exist any further lines in the Burdwan charge on this bank.

MIDNAPORE DIVISION, RIGHT BANK.—38. I will continue the right bank Report to the Hooghly, and then return to the left bank from Musraka to the same out-fall.

At Gopalpore, North of the Oolobariah road, is a new line constructed last year, but requires raising from five and half to seven feet, its present Section being No. 121. Two other new portions are moreover required now at Ragpore 300 feet in length each, beyond which at Chandpore the Section is as shown at Nos. (122, 123) in bad repair and in many places within 20 feet of the river, this requires protection by a retired line.

39. South of Musraka, is the Comarkhalee Khal 20 feet wide and but eight feet deep. These khals, their dams and sluices will be particularly noticed in Part II., I will here only allude to their actual state The dams should be as near the mouth as they can safely be put, and sluices constructed for the necessary dramage, thus abolishing the tributary lines of embankments. The Government lines exist to the Tetoah Khal with the exception of 1,500 feet of zemindaree. Between the above khal (which is 80 feet wide and 12 feet deep) to Guzeiat is a Government line, the northern extremity of which shows Section (No 124) 92 feet from the river, said to have been repaired last year, but the Section which the darogah showed as that ordered is five feet high and bases of 15 and 10, so he has not done full work. There are variations every 300 yards in the level of the crest, and they are much cracked, showing looseness of construction Half a mile South of the last is No 125 showing more attention to the *inner* than the outer slope, the darogah's Section being as above stated. At another half mile South is No 127 repaired last year and neither settlement nor curtailment naturally could have produced this difference between what is, and what was intended, the latter being No. 126. It is much to be regretted that such practice exists, for the flood level shows these so repaired Sections to be not only deficient in height now, but they would not have been strong enough had they been as ordered (No 126), and it is consequently necessary that they be again strengthened and corrected, though such driblets of additions do not sufficiently incorporate with former work, and the Section is not nearly so strong as it would have been if properly made in the first instance

40. Between the Tetoah and Seetapore Khals is a line which has received repairs in patches, No. 128 showing the repaired portion on No. 129 the intervals, which are said by the darogah to have been left undone as the rains came on, and he states that no estimated work

was done during the rains, yet what folly it was to commence what either could not, or from other causes was not completed, for as one weak point renders inefficient a whole line, this money has been thrown away for the repairs (?) have not been continuous and the full Section not given, the lower portions being steep at an angle of 45° giving the whole a rounded form. The slopes are very rough, and the turfing miserable. The intervals unrepaired exhibit an aspect but a degree better than the ruinous zemindaree lines, and are so tortuous as to form acute returns, approaching the river sometimes as near as 20 feet, and covered with jungle

41. The "Seetapore" or "Nouda" Khal is 110 feet wide and 14 feet deep, the embankments on both sides of which are very bad

42. South of this khal the Government line continues, repaired as per No. 130 which Section continues for 120 yards, when No 131 appears, in close proximity, concave crest, rugged, and ruinous, eclipsed only by the adjoining zemindaree line No. 132, such a state of affairs utterly nullifying any benefit intended to be derived from repairs executed, and money spent, even No. 130 is not what it ought to be supposing it to be supported on both sides, and the turfing is very bad indeed.

43. This zemindaree line continues to Googoobarea quite ruinous At Googoobarea it is on the river bank for ¾ mile North of the Gurchumuck Khal, the Government line is also close to the river varying from 45 to even 13 feet distant, scarcely more than 3′ 10″ high and requires entire renewal. The Gurchumuck Khal is 70 feet wide and 12 feet deep, the embankments on which are inefficient in height, the flood line showing itself at 1′ 10″ from the crest, and there is much jungle on them.

44. Between the last khal and the Dusserstey there are 1,000 feet of a zemindaree intervening between two Government lines, the former showing Section No. 133 with the flood line over the crest, and the Government line not much better (No 134) covered with jungle. Many complaints were made here of the effects of breaches, but when the entire line is unserviceable, it is in vain to particularise. The Dusserstey Khal is a small one, only 16 feet wide and 8½ feet deep.

45. Two and quarter miles South of the khal runs a Government line to Kistopore repaired last year, partly outside slope, Section No. 135 and partly on the inner slope No. 136, the former not sufficiently high, the soil is good and therefore the inner slope is strong enough.

46. The Pathulghutta Khal, is 71 feet wide and 14 feet deep. Really till the dams are complete, temporary bridges should be erected over these khals, for at low water the mud is so thick that bearers cannot get through it. I have been detained two hours at this khal. The embankments on it are of the worst possible kind serrated throughout, and presenting an appearance of a series of nodules of earth, the largest being about 2′ 9″ high.

47. Between this last and Sampore Khal there exists about 600 feet of zemindaree embankment all the rest being Government, partly repaired last year as per Section No. 137 on one side only, and very badly too, the crest being only half entire, and much cracked. A portion like Section No 138 intervenes between two so repaired places, little better than a common field bank, with the flood-line above it.

48. Between Sampore and Alpin Khals, is a zemindaree line, almost continuous breach.

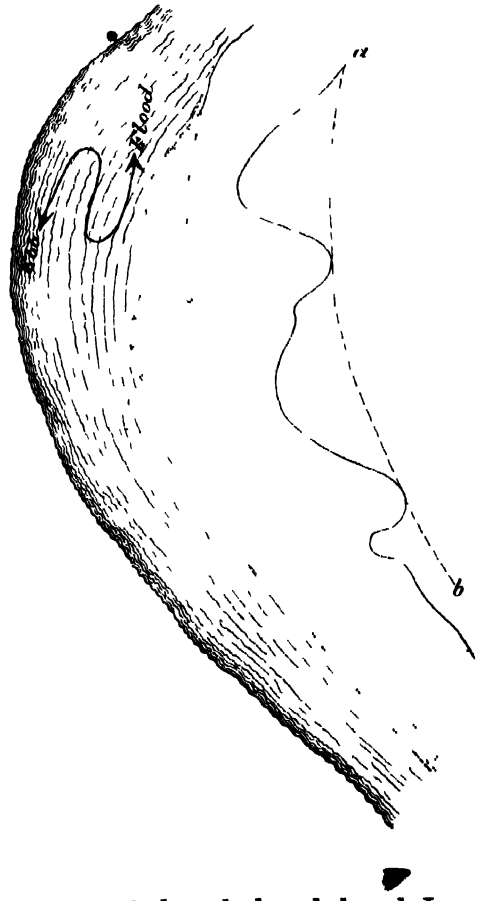
49. The Alpin Khal is 32 feet wide and 12 feet deep dammed but in a bad place The Overseers and darogahs know nothing about the proper method of constructing either dams or sluices even with the plans before them and it is useless to have money thrown away on works of inutility. Such important works as these should be under the immediate supervision of the Officer or his executive assistant.

50. The Rammessurpore Khal is 67 feet wide and 16 feet deep, between the Alpin Khal and which, the darogah has done infamous work, the Section intended and entered in his book is No. 139, but it is as shown in No. 140, it is entirely unturfed yet in many places, and in others turfed only on one side, and the full Section has not been carried out Where the repairs terminate the Section is No. 141, rendering the repaired part quite useless. A small natural water channel actually flows at foot of outer slope, which has been the cause of two breaches. The unrepaired part is very much cracked and trodden down by cattle.

51. Hurrepotah Khal 52 feet wide and 12 feet deep, between which and the last is Section No. 142 very inferior and much serrated, but it is impossible by means of either Section or words to describe the state of the line South of this khal to the Hooghly. I can only state them as being quite useless for any purposes to which an embankment was ever intended to be applied, ruinous and irreparable, the trace being so very devious and irregular.

MIDNAPORE DIVISION, LEFT BANK.—52 I will now resume the left bank in continuation, after para 29, which left the Burdwan Division at Musraka. The river here is contracted in its width, receives part of the drainage of the low tract of the Hooghly valley; and its bed is dark alluvium now instead of pure sand as above. A marked difference occurs in the aspect of the embankments below Musraka, to those above, and utterly inefficient and totally neglected lines of zemindaree occur at intervals between Government lines, over which there is supposed to be exercised proper control for their maintenance and repair.

53 From Musraka southward there is a Government tortuous line the bunds in which are often at right angles to the course of the river and to that of the adjacent line, so much so, indeed, that a new line *a b* would involve less work than the repairs of the old one, and be more efficient

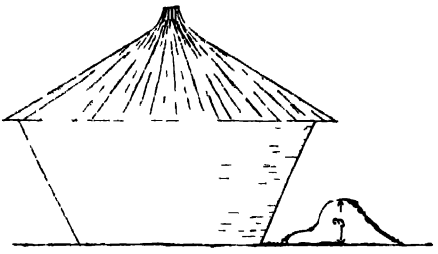


The present Section is No. 66 to be increased to No 67, which was taken from a portion of about 100 feet executed, and which is the only spot on which any work was found in progress between Musraka and the Hooghly. They were not executing the work according to orders in layers, to be consolidated as the work proceeds, but throwing it loosely from top of old Section, whilst the temporary Sections erected differed in level as much as 1′ 7″ in 100 yards. The old or present line is much breached, and though I could get no account of the rise of the flood from either Overseer or Darogah, both new men, (and the villager's report is not to be trusted) the appear-

ance of the crest and inner slope warrants the supposition that the water has gone over them. Reeds and quantity of jungle on the embankments.

The Kotalbunga Khal is two miles from Musraka, 33 feet wide and eight feet deep.

54. *Zemindaree* line South of the khal of the worst description, crooked, inefficiently low, covered with jungle, breached and entirely neglected, *vide* No. 68. Lines of babool and other trees seem to have been selected as those by which to form the embankments as they are plentiful throughout on crest and slopes, the earth having been washed from their roots Huge hayricks in 20 places have been erected just within the embankments, the inner slope having been cut away for their convenience. No. 69 is taken half mile South of No. 68 on this zemindaree line, which must be entirely remodelled and properly lined out. Compare No 67 Government line as it will be with No 68, 69 zemindaree, as it is likely to remain, and the fact of the necessity for taking the reformation into our own hands is apparent enough. If they do not commence their repairs at the time that we do and conform in level and Section to our lines which are contiguous, the whole work should be executed by the Government Officer, and the Civil authority recover the expenditure, for if otherwise, then is Government money expended for no purpose of benefit



55 *Government* line commences again at Jyrampore similar in appearance and trace to that at Musraka, repairs not commenced (27th December) the Section is to be the same as No 67, at present it is as No. 70, the inner slope being wider at base than outer. This Section extends 60 yards, and adjoining it is No. 71, repaired last year, yet that the above-mentioned 60 yards should have been left untouched shows that either proper measurements were not taken by controlling officer, or non-execution by the Darogah, who by the bye, has been discharged; one weak spot renders a whole line inefficient, the neglect therefore is serious. A Section even as good as No. 71 only exists for 130 yards, then comes No. 72 the repairs of which are said to have been given last year, *but on the outer slope only*, and 90 yards again in advance the crest suddenly falls

14 inches. Within another 100 yards the Section assumes the form of No 73 repaired last year, but with a crest two feet higher than No. 72, on the same level of stool. This Section is not so strong in the outer slope as it ought to be.

56. The river widens here, and there is an old line which, though the retired one has been built some years still is allowed to encumber the bank, it should be cut away, and the flood allowed to come in and silt up outer excavations A mile South of Jyrampore is the Dobunga Khal, with embankments on both sides a mile in length. It rises in a jheel, and should be dammed with a sluice in it for drainage. The embankment on the khal can hardly be said to exist, certainly to no good purpose. Immediately North of the khal, and adjoining the last Section, is a small retired line constructed last year as per No. 74, so that the crest is two feet lower than it ought to be, and 1′ 9″ below the adjoining Section. Must be raised, and here is an example of bad construction and arrangement. Section No 75 shows what the intent was, but not carried out. it is loosely raised, and very badly turfed, the crest too is much cracked. The proposed Section is not what it ought to be as regards the outer slope, and no line made one year should require extensive repairs for at least six, much less in the following season.

57 *Zemindaree* line commences South of the "Dobunga" Khal and extends to Khurea Khal rather more than a mile, amidst jungle so thick that a man on foot cannot walk along its crest. It is breached and trodden down throughout.

58 *Government* embankment then re-commence on South bank of the Khurea, which is 40 feet wide and 12 feet deep, embanked on both sides for the extent of the khal two miles. To the South of this spot is only ¼ mile of Government embankment as per Section No 76, which has apparently been neglected for a very long time, for it is dilapidated throughout, and quite inefficient, the (said to be) flood line is within a foot of the crest, but so rugged and weak is the crest, that no current having reached that point would have been resisted, it is a far greater probability that it has gone over and through the serrated crest.

59. *Zemindaree* again for ¾ of a mile vying with the last in the raggedness and wretchedness of its appearance. I said ¼ mile was the extent, but that is by the river, for this line wanders about inland for 360 yards at right angles to the stream, till it meets the "Dara" Khal, a small one 12 feet wide.

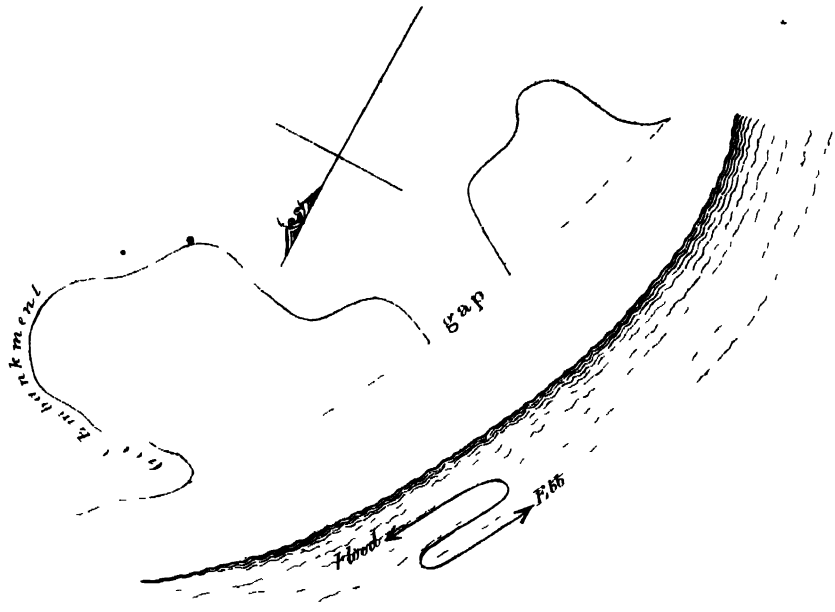
60. *Government* line commences again at Mograjpore with Section No 77 which has been left in that state with repairs as per No. 78 intervening. At Gudaipore ½ mile from Mograjpore is the Gudaikhalee Khal, 28 feet wide and eight feet deep, requiring dam and sluice, the present dam is in the wrong place and cut. The embankments on the khal are very indifferent and tortuous. Half mile South of khal repairs were made last year as per No. 79, but roughly executed and not properly turfed.

61. *Zemindaree* line again intervenes one mile South of Gudaipore, of the same nature as those before mentioned, with such dense jungle as to prevent progress on foot, even breached in several places. They extend to Secalia Khal which is 60 feet wide and 14 feet deep, requires a sluice with three openings, and a dam near the mouth, doing away with the khal embankments which are miserable ones.

62 *Government* line recommences at Secalia and extends to Boalia Khal, scarcely half a mile as per Section No. 80, these are on the latter khal which is 64 feet wide and 15 feet deep Sluice with three openings required as before.

Zemindaree line hence continues to the Toltolah Khal in quite as bad a state as those last mentioned, Section No 81 is the best portion of them, the flood level being over the crest They have been breached throughout and covered with jungle. In many places they are mere little mounds two feet high scarcely observable as embankments and not worthy the name Toltolah Khal, 70 feet wide, 11 feet deep, requires dam similar to the last, near the mouth and abolition of khal embankments.

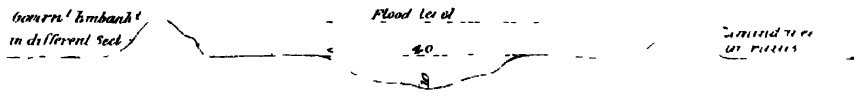
63. *Government* line from the Toltolah Khal was repaired last year in an indifferent manner, and half a mile South is a new line constructed last year, but which has been joined to the old line at so sharp an angle and in so awkward a direction, that it must be relaid out at both ends, and the Section, No 82, not sufficient on outer slope, nor high enough, must be strengthened again I have before remarked on the want of management, by which embankments require additions two years successively. At the end of this newly-made line, the old one stretches away into the country in an extraordinary way, for nearly a mile, and ends abruptly at right angles to the river; there is then a gap, and the line recommences with another wandering course, the whole being useless, and it is a matter of much surprise how the embankments could have been allowed to remain in this state so long, for there is no high ground or any other reason why this gap should have existed, nor why the line has been permitted and *repaired* in this state.



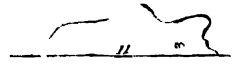
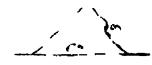
64. A new and better line is projected for this season as shown in red, two and a half miles South of Gwalapotah, Government line repaired last year in patches as per Section No. 83. The turfing is very bad indeed, the crest is uneven and much cracked, the work must have been loosely and carelessly performed The unrepaired portions are 15 inches below those repaired, and sometimes more, presenting an appearance thus.—

But the repaired parts of last year must be again strengthened, this to Section No. 84, proving the work of last season to have entailed loss of money and turf.

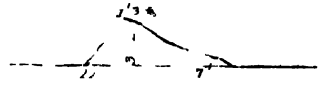
At Mirzapore and in several spots North and South of it, the line is as per No. 85, which the Darogah states to have been repaired last year. Now considering the Section, the level of the flood line, and general appearance of the embankment, the neglect has been gross, and though the Darogah has been discharged, that will barely mend the evil, as the present one may do likewise. I shall offer some remarks on this matter in Part II. The excavations of this line have been cut from the very toe of the slope. The khal at Mirzapore runs up past the Bungalow, on one side are Government embankments, and on the other, zemindaree, which generally present an appearance as below



65. South of Mirzapore the Government line presents Section No 86, repaired last year, and immediately adjoining is No. 87 left untouched. At Balchetty, north of the khal of that name, is an embankment repaired last year, presenting Section No. 88, the turfing of which is so very badly done that it has no hold on the soil, it was originally nothing but a few loose clods most carelessly thrown on, without a particle of grass in them, and here also a new line is required, though the embankment in rear of which it is to be made was only repaired last year. The necessity for this must have been apparent last season, and consequently the money expended on the repairs has been wasted. Between Mirzapore and Balchetty is moreover three quarters of a mile totally neglected, its

Section is  varied by  round

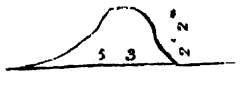
holes and breaches, and in two places

the Section is  the flood level being

more than a foot over the crest. This must have been long neglected, and renders the Embankment Department open to censure, not only as negativing the value of the repairs given, but as a bad example to the zemindars who are only too ready to point to it; and this is rendered evident by the fact that Sections Nos. 86 and 88 are on either side of the above inefficient lumps. The Balchetty Khal is 34 feet wide and 12 feet deep.

66. *Zemindaree* line South of the khal to Bowanipore two and-a-half miles, in which distance an embankment can hardly be said to exist, so entirely neglected, disunited and ruinous is the whole. The Gajuncool Khal is in the above distance, 98 feet wide and 20 feet deep, and immediately South of Bowanipore is the Bagran Khal 80 feet wide and 12 feet deep.

67. *Government* embankments here exist on both sides of the khal, they are of imperfect Section No. 89, but those on the river adjoining are worse far; see Section No. 90 with a serrated concave crest, cattle trodden, turfless sides, and seem to have been, like those in para. 65, entirely neglected. Quarter mile beyond the last Section is No. 91, an exceedingly tortuous line, there is a new line in contemplation here, but I wonder much at these lines having been allowed to be so long uncared for. One hundred yards beyond is a low line not larger than a field boundary and anon it disappears. After an interval we have No. 92, in which is a ruinous sluice with wide breach on both sides, and a streamlet close along the foot. I could not have imagined a more wretched affair, split, breached, worn by cattle and covered with jungle. Here too exists another strange matter, *viz.*, that a piece of embankment of Section No. 93 should adjoin No. 92, but only 150 feet in extent! repaired lately, a mockery almost of the ruin on each side. The turfing of this piece is very bad indeed. The native Darogahs and Overseers seem here to have been rejoicing in uncontrolled malpractices, and extraordinary irregularities. I said that the ruin existed on either side of No. 93. On its South end the neglected line is 900 feet in length, when No. 94 appears, somewhat better in form, but in strong contrast, and only 630 feet long, half bare of turf, sides gullied and cracked; the repairs of last year must have been most carelessly executed. A sluice is required at a breach, *cut annually and open now* (28th December)! Adjoining No. 94 is Section No. 95, which with slight variations meets the zemindaree line which extends to the Hooghly.



68. Such are the embankments on the Damoodah exactly as I have traced them in December 1852, on which I will offer a few remarks in Part II.

Part II.

1. In the Burdwan Division, I have alluded to (paras. 9, 12, 17,) the lines of new embankments having been carried too far inland; the reasons against such practice where (as in the above cases) it might have been avoided, are, that it leaves much land and some villages unprotected. In the case of the Salalpore and Selimabad line, it brings a reach of the river at right angles to its direction. They are beyond the position where they can benefit the river bed but rather permit lateral expansion of the flood-water, injure the banks and promote sand deposit, and lastly from the fall of the country, which is highest at the margin of the river, the Section must be higher than it need otherwise have been if nearer. These I think are strong reasons against the practice where a choice of direction is open.

2. In para. 10, I alluded to the great probability which exists of the embankments constructed last year and now constructing, being cut next rains, and gave the reasons for the supposition. There are other places also which stand in a like predicament, *viz.*, those *in front of which* villages yet remain, and who last year cut *the strongest lines in the Division* and in places the most remote from the river, and where most improbable for a natural breach to occur. I would draw serious attention to this matter that the Civil Authorities be directed without delay to negociate for the retirement of these villages within protected limits. I would also draw attention to my No. 1725 of 26th August 1852, relative to the remodelling of the embankment establishment, that it be urged on the Government as the only means for protecting their works from the wanton destruction which up to this date has taken place, and rendering the vast sums spent of any avail for the purposes for which it is given Moreover, I would again point to the necessity of stringent protective regulations for the embankments to provide against the following serious evils.

1st. Cutting or injuring the embankments and dams.

2nd. Cultivating within the limits assigned to the embankments, their berms and excavations.

3rd The trespass of cattle.

4th. Erection of huts, &c., on the embankment limits.

5th. Interfering with the sluices without permission from Embankment Officer.

6th. Neglect of zemindaree lines, if these lines are not taken under the care of the Government.

I may be considered importunate in thus often alluding to this subject, having been told that it is before Government, but my reason is that these measures be carried out and the new establishment organised before the season of danger and difficulty. The question relative to the value of the embankments I feel to be one of the most important affecting the interests of these provinces, and I am certain that the greatest advantages will accrue from their retention. These advantages can only be gained by their retention efficiently and by perfect protection, and willing as I am to take the responsibility of the assurance of success, such assurance can only be genuine and surely based when the system and means that I advocate are afforded.

3. It will be seen from para. 12 that work executed during the rains does not prosper. From the entire report may be gathered that the greater part of the work was executed before the rains, and is the best.

In the Midnapore Division no portion has been attempted during the rains, though here I admit an error has been committed, for though weakness has occurred in the Burdwan Division in lines completed during the rains, there are many parts of the Midnapore lines which required all the energy, labor and attention that could have been given, for though permanently effective work could not be given, temporary protection might have been given in the rains till the proper season came for the permanent work. Again, there is no objection to new work being carried on during the rains which is not to be assailed by the floods of that season, and if executed behind a line which for that season is secure (and which should be arranged for if possible) may be all the better in the following.

4. I have no hesitation in pronouncing European overseership by far the best, the professional instructions are better understood and construction better attended to, for an interest in the work can be imparted to them which cannot be instilled into the native; and where there is a service of danger, such as attention to weak points during a flood, or entrapping a "cutting" party, the European is the man to depend upon.

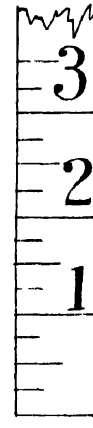
5 The tributary streams and streamlets should in almost all cases be dammed, with sluices in the dams; streams continuous from one river to another used as canals of traffic may be exceptions. The dams of these khals should be near the mouths in continuation of river embankments, and the inner lines abolished as useless. Those that are not dammed should have wooden bridges over them for the facility of traffic and inspection.

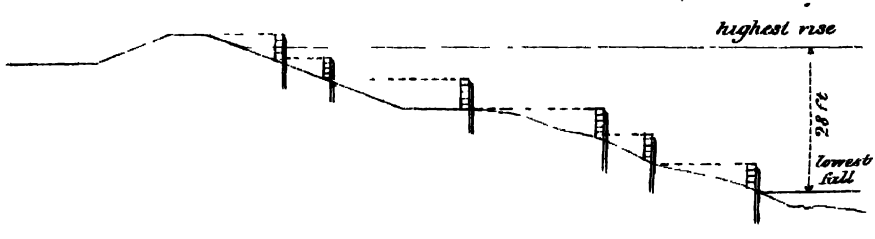
6. I feel sure that it is as necessary a portion of the work of preservation of the embankments by sloping off the banks of the river as the repairs to the embankments themselves (see ante paras. 16, 20, 23, in illustration). Many a retired line will be saved by giving to the river bank such a beach slope as shall cause the current to glide by rather than eat into it. This has been particularly enjoined on executive Engineers for the expenditure of hundreds in this case may save thousands.

7. In giving instructions to Executive Engineers, I have observed the principle that one weak point nullifies the benefit otherwise derivable from a well, constructed line. I have found in many places, particularly in the Midnapore Division, that an embankment raised one season has to receive an addition on the following, and that many lines have been overtopped by the floods that were considered safe. This is owing to the absence of certain information regarding the rise of the floods The villagers, whose word is often the guide, are sometimes interested one way or the other, and are so apathetic as to give statements wide of the truth, whilst the native establishment can be as little relied upon for data of such importance. In regulating the height of his works in the cold weather the Executive Engineer must frequently be in error as to the correct flood-mark, and the value of the embankments in the salt districts is not tested by their capability to resist the highest rise of even the freshes, but a salt-flood driven violently up the rivers by a Southerly gale, raising the level of the water, if at a period of high tides, 3 or 4 feet above the other level

A guage for noting the height of the flood rise was circulated in September 1851, by the Military Board, but as no reports of its having been used have appeared, I imagine it to have been difficult of application, in fact I have discovered serious impediments to its utility. A position could not always be found for it, nor a tree or post to fasten it to, and the box would get clogged with fine silt. It would be unstable on account of the looseness of sands in which it might be imbedded, and would require guys or struts for its support and a telescope would be necessary at a high flood, to read off the scale, for the distance would be

often great. The following is a simple arrangement by which an accurate register can be kept of the exact rise and fall of the water. The figure in the margin [below] shows one portion, a plank seven inches wide, five feet clear out of the ground, divided off into feet and thirds. These several guages are placed from the level of lowest water to show the whole range to top of embankment, so placed, that they can be easily seen at all times by the observer. The upper one to be on a level with apex of embankment and the lower one in the water at its lowest fall. The upper mark of each is on an exact level with the corresponding mark on the bottom of the piece above it as shown below.





A register is to be kept as per form annexed.

BURDWAN DIVISION.

Register of Floods (or Tides) in River ( )

at

	Date.		Time		Height		Height shown by guage of flood-rise between crest of embankments		Remarks
	Month	Days	Hours	Min	Feet	Inches	Feet	Inches	

RESULTS.

Greatest Depth, ...	0	0
Greatest Height, ...	0	0
Whole rise, ...	0	0
Begun to rise, ...	0	0
Highest rise below crest of embankments, ..	0	0

The observations to be made as often as possible during the season of rise and fall, and all remarks relative to the weather and other phenomena registered in "Remarks". Lithographed forms to be furnished to the Overseers, and the guages to be set up at every bungalow or convenient spot. Every Officer during inspection to take the register himself, and a copy to be sent to Superintending Engineer half-monthly.

8. The zemindaree lines have been represented to be in a neglected and totally inefficient state, and the reason is obvious, as far as I can gather from the parties themselves, and which I believe from the aspect of affairs to be the case, *viz.*, that it is to the interest of the zemindar

that the least possible or no outlay should be incurred on the embankments by *him*. The lands appear to be sublet to persons styled putneedars, for certain rents, the zemindar thus secure of his rent cares no more about the produce of the land, but the putneedar, who is of course anxious to realise the greatest amount of advantage from it, is directly interested in the embankments though too poor to pay for repairs that would afford him protection, admit of his paying his rent, and realise a small profit.

The zemindar knows that if Government repair his embankment the amount for such work would lessen his rental of the lands, and as he enforces full payment from the putneedar, it is altogether against his interest to countenance an improved state of affairs at his cost Under these circumstances I despair of seeing any amendment, for if left in their hands, they will do the least possible, and as uninterested in results, they will not enter into the calculation of either the causes destructive to embankments, or those necessary to counteract them. No beneficial result can therefore be hoped for, and the interest of Government cannot too earnestly be laid before them to take these lines into their own hands and permit the whole to be kept uniformly in efficient order, for the weakness of any one portion of any one of these zemindaree lines, renders useless the sums of money laid out by the State in those which are adjacent, and let me add that the proper system of maintaining embankments so as to obtain the greatest amount of benefit, is founded on laws and maxims of science, of which a zemindar has no cognizance.

9. Copies of my remarks on the works of the two Divisions through which the Damoodah flows, will be sent to the Officers concerned, that they may offer such replies relative to their condition and construction herein noted, as may be explanatory of the same, for the disasters which have hitherto occurred to the embankments and country, are attributable to the limited amount of former efficient construction, the want of protection and educated establishment, and the mistaken ideas of the guiding principles of the action of rivers, and means by which those principles may be turned to the double improvement of the rivers themselves and the country through which they flow.

Part III.

1. Inundating rivers, says Rennell, occupy the highest parts of the tracts through which they flow, and the effect of those inundations is, to cause

the grounds adjacent to the river to rise to a higher elevation than those remote. The reason is, that unequal quantities of sediment are deposited according to the distance the inundation extends laterally, the matter in suspension becoming for an obvious reason, less and less as that extension increases. The overflowing waters purify themselves gradually, so the effect produced is that of a moderate slope, *highest at the margin of the river and lowest at some distance* After the first passage of a flood, the waters of the inundation traverse the lateral space at the slow rate of half a mile per hour, whilst in the bed of the river the velocity is five and six miles an hour; this is illustrated by the continuity of the motive inundating column having a greater effective resistance arising from its small depth as compared with the greater depth of Section of the river.

2. The Damoodah follows low the above land, being on a higher level than the tract through which it flows, (1) it is also higher than either the Hooghly or Roopnarain; levels recently taken showing it to be north-west of Burdwan, 40 feet above the latter river, the fact is moreover plain, from the circumstance of the tides passing much further up the Roopnarain, they extend north to Guttaul, 25 miles above Gopeegunge, which is exactly opposite to Omptah, the limit of the tides in the Damoodah. At the point, where the above level was taken, there was a regular fall, the entire distance, such is also the case at the lower portion, for in 1850, the inundation from the right bank of the Damoodah flooded and carried away part of the Ooloobariah road close to Koilah Ghaut, on the Roopnarain, having traversed the country without check for nine miles.

(1) *Vide* Sections I, II, VI, VIII Pl 4

3. Major Baker in his memorandum of 17th June last, para. 5, states, "that it is dangerous to throw a considerable portion of the water of the "Damoodah into the Hooghly, except where it now discharges itself," and such is undoubtedly to be avoided, but not for the reason given. It is a good reason for keeping up the embankments and protecting the country between the rivers, *viz*, the *silt* swept forward by the Damoodah would not "drop at once in the Hooghly and form shoals," for both rivers are affected by the freshes at the same season, and the flood of the Hooghly has scarcely any power against the velocity of the ebb. Sand and silt are not dropped till the velocity is less than one or one and a half miles per hour. Now the velocity of both Damoodah and Hooghly separately, during the only portion of the year when the former is loaded with silt, is five miles at least, and when they unite, that velocity must be

greater, and if there were no impediments the silt and sand would all be carried out to the Sandheads, where in fact very much does go, as those sands are encreasing, but the cause of the shoals below the confluence of the Damoodah and Hooghly, *is the Roopnarain*, and a glance at the formation of the river will show it at once (*vide* annexed Sketch) The Damoodah enters the Hooghly at an acute angle, mingling streams nearly in the same direction Below the confluence is a right-angled reach *in prolongation of which is the Roopnarain*, the freshes of which oppose those of the Hooghly *directly across their course* and checking the velocity during the latter part of the ebb's duration, cause the deposit of silt and sand The Roopnarain is similarly affected, each checking the other. Look at the huge sands at the mouth of the Roopnarain, deposited there by a similar check from the Hooghly, to that which forms the "James and Mary" by the influence of the Roopnarain I have more than once watched this during last rains and am satisfied that the Damoodah has nothing to do with it, but on the contrary is rather an auxiliary to the Hooghly.

4. At para. 12 it is stated "the embankments could be made of "sufficient Section to confine such floods of the Damoodah as have been "recorded, but the unavoidable effect of such a measure would be to "raise the river bed, to necessitate a constant and proportionate increase "to the height and Section of embankments to stimulate the growth of "shoals, &c., &c." Now having not only given much study to this subject, and sought for the opinions of every Engineer whose knowledge or experience in other parts of the world could aid me, owing to the alarming picture here presented, I find that instead of any apprehension of the above evils to be entertained from the permanent establishment of embankments on both sides, exactly the reverse is to be expected, as I will attempt to show

5. *First*.—Of all the embankments are many of them now more than equal to the greatest pressure that could be brought against them under any circumstances, as is clear from the explanation given in Part I. para. 10, nor, as I will show, need they ever exceed that Section.

Secondly.—As regards the river bed, I have found from observation, corroborated by the accompanying Section across, (1) that sand has only been deposited in those parts where, either from some obstacle, or from the withdrawal of portion of the flood waters by branch channels, such as the "Canna" and "Gojah" Nuddees, the velocity has been checked and lateral diversion ensued.

(1) Pl 4 See Nos I, II, III, VIII as compared with Nos V VII

6 Again, it is only during the freshes that sand is held in solution by the river, and it is at that time that its velocity is far too great to permit that substance to be deposited except under the circumstances noted above. Any body who views the Damoodah water when the freshes are over, can bear witness to its transparency and the absence of all foreign substance, nor could the velocity at that season move the sand over which the water flows, for the action of the floods has given it a *set* on the bed. The clearness of the water may be mainly attributed to the Damoodah receiving no drainage or tributary, from 30 miles above Burdwan to Omptah, a distance by the river of fully 120 miles. Below Omptah it changes its character, flows through the valley of the Hooghly, and receives a great part of the drainage of the two Mundul Ghaut estates, yet here with all this accession of volume the channel bed is maintained narrower than it is above.(1)

(1) Pl 4 Sections Nos IX to XII

(1) Pl 4 Sections IV and VIII show 20 and 23 feet between bed and flood, or 23 and 26 between top of embankments and bed, and the *average* of 3 Sections taken in 1827, shows only 24½ between bed and top of embankments, and Nos V and VII show 28 feet above bed or 31 from bed to top of embankment.

7. It was stated 25 years ago, and attempted to be proved by Sections taken at an interval of seven years that the bed of the Damoodah was silting up at the rate of 7 per annum Now had such been the case, the bed would now be 14 feet higher than it was then, which is not the case, the particular spots, unfortunately for the reporters, where those Sections were taken, being where lateral diversion or great widening of the bed occurred, and they have shifted since, to be replaced by others, though no general rise of the bed has, or indeed can occur from what has been said Hence we may fairly give up the idea of silt or sand being deposited even under the present unfavorable circumstances attending its banks, but I will now prove that the bed, instead of being liable to silt from the establishment of the embankments on both sides, will *be scoured out* and *improved*, and protection afforded to the country (2) I am quite aware of the dangerous power of floods such as come down the Damoodah, but I feel confident that the principles which I advocate will give control over that power, and on that account urge the necessity for their adoption.

(2) Pl 4 Sections Nos V, VII

8. In the following *Figs.* it must be remembered that they are drawn to distorted scales for the purpose of showing the vertical distances more clearly. The same letters are applicable to both *Figs*

Fig 1

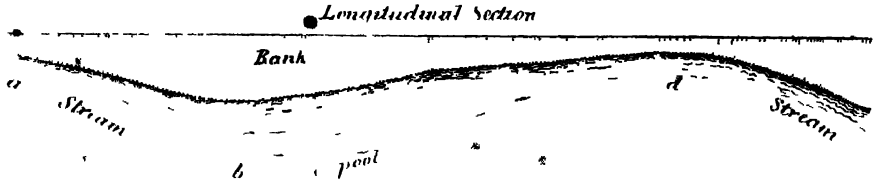
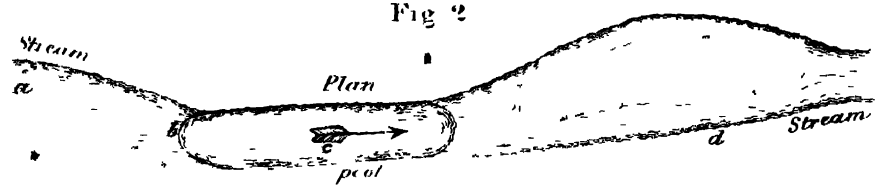


Fig 2



At *Fig.* 1. is a stream, which moving (on the principle of falling bodies) with an accelerated velocity as it descends the slope, acquires at *b* the power to excavate its bed and form a pool, *c*; but this process is destructive of its own power and a counterfall is thereby established from *c* to *d*. A similar process is then commenced from *d* where the natural fall restores the power. The counterfall *c d* acts as an obstacle to the direct course of the stream, and being from that cause no longer able to overcome the resistance of the bed, it acts laterally on the banks, which become farther apart as you approach *d*, the current getting feebler, till top of the counterfall gained, the equilibrium is restored and the same process is repeated. It is thus that *Fig.* 2 can be traced from *Fig.* 1, and the plan drawn from the Section. Thus it is that Nature deals with river beds, and the effect above described must have been witnessed by every one who has seen a river in the dry season, which plainly discloses the operations that have been carried on during the season of flood which is the real governing state of the river.

9. It is seen how the variable Sections of a river are thus formed by the corrosions of the banks when they are corrodible, and the stream not able to act on its bed. This is Nature's own doing and is an established fact.(1) With the river formation, however, I will not interfere, but having established the principle on which the working of the stream is ordained to act, I will apply it with equal truth to the reverse of the above case, and it can only be just to conclude that, on the above facts, if lateral diversion of the current beyond its natural limits is permitted, encouragement is immediately given for further action on the banks, that is, if embankments do not exist on one side, and the flood wanders from its channel, the velocity is diminished and the embankments on the other side are either eaten into, and if not breached, undermined. Whereas by the establishment of solid works, such only as I have before referred to, on both sides, you compel the current to act in its natural and legitimate way in the scouring of the bed, and examples are not wanting of this effect.(1) The river Hooghly at Calcutta is far narrower than at Diamond Harbour, yet the current during the most violent freshes does not corrode the bank of the river on either side at the former place but maintains an unencumbered deep channel, whilst at Diamond Harbour from the diminished velocity caused by greater friction from larger wetted surface, and lateral expansion, it is so rapidly eating away the banks that the Government buildings are endangered and must be re-built this year. The lateral action can be witnessed all the year round on the banks of the Ganges, where during the period of the feeblest stream the lateral action is at work on the banks, and in the widest parts.

(1) Pl 4 Sections I, II, III, IV have eaten into the bank from expansion and friction of surface overcoming power of stream, but V and VII have scoured it out and maintained it clear

(1) Pl 4 Sections V, VII

10. At para. 6 of Major Baker's memo. it is stated that "645,333 "cubic feet of water per second has to be disposed of during the period "of a flood, and that at an average velocity of three feet per second, it "would require a channel two miles wide and 20 feet deep." There are two things here to be noticed, first, that the channel is not anywhere two miles wide, but in some places not more than three-quarters of a mile, and in these narrower channels, the embankments intact on both sides, have passed the flood-waters, the inference from which is, that three feet per second does not show the velocity, three feet per second is hardly more

than two miles an hour, whereas when the above quantity of water is passing down, the velocity is fully three times as much, and that it must be so, the fact of its passing through the narrow channels and not over them is proof (1). The second matter connected with the above statement is, that the quantity of water though very great even for a channel like the Damoodah's affords only the more power to be judiciously employed for effecting an improvement of the bed for even 6,45,333 cubic feet per second, is 67,392,000 tons per hour, which at the elevation of the river basin, and a horse power being 33,000 lbs. gives 10 million horse power, which distributed over the length would give about 47 horse power to every yard of the river's course, the greater part of which is now lost by diversion over the country and friction on so extended a surface. The Roopnaram from Pertabpore to Koelah Ghaut, a distance of 30 miles, has a breadth of channel scarcely exceeding from 150 to 300 yards, and the volume of water it pours down is enormous, receiving as it does, the Selye and Tarrajoole just above Pertabpore, yet does this bank corrode but very slightly during that whole distance, and the *bed is perfectly clear.* It must be further remembered that there is no accession to the original volume of flood water that passes down the Damoodah for 120 miles of its course, save what may be added by rain falling on the area of its basin, for there is no land drainage in that distance, the floods therefore as they traverse the river's course are by time and friction much reduced in power the lower they travel.

(1) Pl. 4 Sections V, VII, IX., X

11. The effect of limiting the flood channel is to increase the velocity and not to raise the level, this is an important fact to prove when advocating the retention of the embankments on both sides, and as I have shown that the embankments themselves, when constructed *as they are now being,* are capable of resisting the greatest force to which they can be exposed, if I can also show that the level of the flood will not be raised thereby but that the bed will be scoured and improved but little will be wanting to turn the scale in favor of retention

12. In my No. 3063, of 7th December last, paras. 7, 8, 9, I noticed the facts of the disastrous effects of weakening the power of streams by diversion of the waters. I brought forward the case of the silting up of the Euphrates when the current was diverted by the western cut made to lessen the ravages of inundations, and that a marsh was formed thereby breeding pestilence and death. I also brought forward

the attempt to lower the inundations of the Tiber by a canal cut by order of the Roman Senate, but which did not reduce the level one inch. In contrast to the above was the fact of the river Po in Italy, which, when its various branches were united into one channel near the Towns of Placentia and Parma not only caused a *deepening of the bed* but the neighbouring marshes were ultimately drained into it.

It has been supposed that the Po silted up its bed. Not so. It is the "Lamone" which enters the Po near St. Albert, hence the mistake, and to show that the silting of that river is peculiar to itself, and has no reference to our present subject, the détritus brought down by the floods of that river is calcareous which *hardens* as it *is deposited.* This was stated by Professor Vignoles in a lecture at the London University, and that this deposit is "only in the upper or gravelly part of its course, there being "no perceptible rise in the sandy channels" I must here repeat also what I entered in that letter, an extract from a valuable work, on the improvement of the Tyne which improvements have been carried out. "(P. 49) Where the river has a wide encumbered bed with sand-banks, "there is so much more resistance offered to the action of the stream, "than where the bed is narrower, that there is less available power to "transport or scour the deposit, therefore the improvement of the bed "is required to be looked to, and *the area restricted*"

Guhelmini an excellent Italian Engineer says, "If we restrict a river's "bed by art, *we cause it to deepen its bed,* while if the bed is too wide, or "divided into several branches its bottom will be raised in proportion." (1)

(1) See Pl. 4 Sections I II III VIII as compared with V VII in illustration.

This effect is the same as that which a permission to flow over the country would produce increase of volume then does not produce higher level, on the same reasoning that the reduction of the volume, as in the instances cited, does not lower the level. "The "elevation of the Po in floods," says Frisi, "is not affected by the "accession of the Reno, neither is the Rhine after the junction of the "Mayne."

13. Thus I think three important truths have become manifest. The first is, that the Damoodah silt is deposited in places where the current is weakened by diversion, and that the deposit of silt in all inundating rivers is highest on the margin, and decreases in land, forming a glacis from the edge of the river to the interior where a marsh would most likely be formed.

The second is that the abstraction of the water from the natural channel causes decreased velocity, consequent action on the banks, and prevention of an efficient scour of the bed, and *vice versâ*, by restricting the channel, the scour is effected by means of the increased power gained.

Thirdly, that there is, from the above reasons, no cause to suppose that the river bed will rise when embankments are constructed on both banks, but quite the reverse, and that the embankments of their present Section are quite capable of resisting the greatest power of the current, and that the level of floods will not be raised by their permanent retention on both banks.

14. Let me briefly allude to the project suggested by Major Baker, and which under the circumstances as he has stated them, is the most favorable of all that has been brought forward, but I think that viewing it under the aspect I have given it, the result is not so favorable. It is proposed to abandon the right bank barrier, and permit the uncontrolled flow of the water over the country. I know that just below Burdwan and for several miles above Omptah, there is no elevated tract midway between the two rivers, but that the waters from the Damoodah flow across to the Roopnaram But even if in the central portion of the river's course there were this tract that would retard the progress of the floods, look at the annual deposit of silt *highest at the margin of the river* which would prevent the return of the waters, (unless with very expensive drainage works) and cause the formation of a stagnant marsh in the interior. Then mention is made of compensation to the ryots, but what can compensate them for a permanent banishment (for permanent it must be if they expect to be annually submerged) from their villages and when it is truly asserted that the tract of country "will be cultivated if *at all* under considerable risk." The loss to the revenue will be complete as regards that tract, and which I am of opinion will be found to be far more extensive than imagined. But why should it be given up to waste and desolation or so many hundreds washed out of their homes? I hope there is no necessity for so extreme a measure.

15. As regards the breach at "Bangamarra" alluded to in Major Baker's 14th para. there is a village of that name on both banks, and whilst the ground on the right bank at that spot is high, that on the left is very low indeed, so much so, that the inner slope of the embankment is 18 feet high (*vide* Section No. 46). Breaches have constantly occurred

at this spot and the floods find their way down to Serampore, and below that, returning to their old bed by the Camarea and Mundorea Khals, thus I fancy an error must have somehow crept into Major Crommelin's report by the substitution of the right bank for the left, for so serious have been the breaches in what is called the Moohunpore line behind Bangamara on the left bank, that an entire new one has been constructed higher and stronger than those made before, which have been breached from their inefficient Section.

16. The expense attendant on the construction of a line of embankment across the country from the Damoodah to Roopnaram and from that a backbone line up the centre of the tract, would cost quite as much as the entire remodelling of the right bank embankment in an efficient manner, in addition to which I may add, that as far as the lower Mundul Ghaut estate is concerned, an immense inner embankment extends across the country from the Boxee Khal on the Roopnaram, eight miles above Koela Ghaut, to the Damoodah, skirting the Gyghattee Khal about three miles above Musraka This embankment is now on an average 16 feet high with slopes in proportion.

17. Marginal references have been made to the Sections in Pl. 4, which have been with great care taken by three different Officers during the month of December last completely across the channel of the Damoodah, embracing the embankments and the level of the country on both banks They serve to prove all that has been advanced in favor of retention in an efficient manner the embankments on both banks.

Nos. I. II VI. VIII show the effects of the deposit, as alluded to in para 1, of Part III., forming a greater accumulation on the margin and sloping towards the country, where inundation has occurred, and this must increase as long as the waters are allowed to wander uncontrolled, and every year will add to the baneful effects of the formation of stagnant marshes inland.

18. In 1827, from Sections taken at three different places on long sandy levels, the average height from bed to top of embankments was shown to be 24½ feet, now Sections Pl. 4. Nos V. VII. show 28 feet between bed and flood, or 31 between bed and top of embankments, and even Nos. I. II. IV. show 23½ below flood or 26 below top of left embankments, so no permanent silting has taken place, and the narrower and protected channels of Nos. V. and VII. prove the fact of the scour that takes place with the increased velocity, whilst Nos. I. II. III. IV. (but

especially the two first) prove the accumulation of encumbrances of sand, from the over-extended channels, the difficulty experienced by the stream in carrying the sand forward, and consequent corrosion and greater expansion laterally. This too, I think, entirely refutes the anticipations of Major Baker, in para. 12 of his report, alluded to in para. 4 of Part. III. of this, that the decreased area "will stimulate the growth of shoals, &c."

19. Sections IX. to XII. show the form of river bed below the limit of the tides, where the constant flow and re-flow of the water has kept the channel well open and the freshes scoured it out. Here too is shown that ample exit, (XI. XII.) is given to the floods that pass down, so that there is no fear of any rise of flood above that shown in Nos. V. VII., which have received and passed free the entire volume, or that alluded to in para 10 of this part.

20. Thus I have endeavoured to collect a mass of proof and precedent which when well considered and referred for the decision of Government, cannot, I think, admit of hesitation of that decision being favourable to the protection on both sides, and that it is worthy of the deepest consideration, the great and important interests involved will prove, and it must also be considered that the fact of failure, disasters and remission of revenue, up to this date, show that the system hitherto of neglecting the efficient maintenance of these works has been delusive and wrong, and thus there is additional evidence in favor of the proposed amelioration.

I have the honor to be,
Sir,
Your obedient Servant,

H. GOODWYN, *Lieut.-Col.*,
Superintending Engineer, S. E. Provinces.

Abstract of No. 4005, 10*th February* 1853.

PARA. 1.—Reports on the River Damoodah, embracing every subject connected with its embankments, bed, banks, drainage and inundations, and divides these under three heads.

" 2.—Notices the point from whence the embankments commence on the left bank, the dimensions to which they have been renewed and repaired, and the flood-height upon them of last year, and the highest rise for many years.

" 3.—Bay of Ragubpore already reported upon, notices the nature of embankments at that place; opposite dangerous bend of Banka Nullah considerably strengthened, and river bank sloped off at that place, before and after the rains.

" 4.—Excellent lines of embankments constructed before the rains at Jojootee; from Belcoss to Beharpore will not require repairs for several years, protection ordered to be given them by bamboo stakes and fascines, and slopes to be extended

" 5.—Villagers cut breaches in the embankment at Edilpore and Catgola during the rains, which have been reported upon, these have been substantially filled up since, and the latter village removed within the embankment. Renewed line from Edilpore to Noutungaon in excellent order, completed before last rains, in continuation, the line is being straightened and increased in Section from Noutungaon to Hautsimul.

" 6.—Notices a double row of large trees from Catgola to Hameerpore on the outer edge of river bank, embankment not far from river, river bank corroding, and suggests the trees being half cut and allowed to fall over the bank, to prevent its further erosion. Increase of Section recommended to the embankment between Catgola and Chotepore from soil being light in that distance. Huts noticed close to the heel of embankment at Hautsimul and eastward of Chotepore, villagers destroying the embankment, which calls for remedial Regulations to stop the pernicious practice.

PARA. 7 —Represents a scene of desolation at Debda caused by a breach 21 years ago; shows increase of Section to the embankment at that spot, and in continuation to Futtehpore.

„ 8.—Futtehpore to Palnah, line in good order, but not sufficient in height 15 inches below the flood of last year, being raised to that of the preceding line, soil good and its slope 2 to 1 quite sufficient, its curves to be taken out and remodelled, further on to eastern end of Palnah old line, a new one under construction Between the Western end of the great Sulalpore new line and Palnah, the embankment is being strengthened beyond flood-level. Cultivation between these villages and at Futtehpore brought up to toe of outer slope, for which there is no remedy River bank might be sloped here with advantage, soil yielding.

„ 9 —North of Sulalpore a mile of new line constructed, in rear of Selimabad, before last rains, extending to Canna Nuddee, too far in land Bad alignment, much land thrown outside the embankment, and unprotected, and hence prevents the scour of bed of river, course of the reach South of Dadpore is thus at right-angles with the embankment, and should not be permitted Remarks that this occurs in more than one instance Dam across the Canna Nuddee should have been placed nearer the mouth, had it been ordered by the Board at an earlier period, it has been placed in continuation of the Selimabad line Describes the dam, which is considered very creditable to the exertions of the Executive Engineer and his European Overseer. Land between dam and river brought into cultivation and submits the question of property of that land, for decision

„ 10.—Represents difficulties of constructing a new line through the village of Jamalpore. Encloses an accurate sketch of the village on which the line proposed by the villagers is marked. Old embankment on the river bank threatened, the bank itself being broken and no

space left to slope it. Inner line necessary behind the village, which should run 1,000 feet from the old embankment. Considers the embankments quite strong enough for resisting floods, enters into a detail of the weight of material, as opposed to that of flood-driven water in a gale of wind. Gives a Section of the Selimabad bund, and observes that, if breaches do occur as they did last year, it must originate from the acts of the villagers, or zemindars of the villages of Selimabad and Jamalpore, which is to be guarded against

PARA. 11 —New inner line between Culnah and Debdara described, a better one might have been chosen, round the village the new line breached last rains to the extent of 140 yards, another new line also noticed extending to South of Bistopore, the point at Debdara to be strengthened, and a new inner one also recommended, another new line noticed from Debdara southward to below Bistopore, four breaches on this line, one of them very serious, 13 feet deep, through which much water escaped into the country, and extended to a distance of 14 miles Assigns causes for the breaches, and suggestions offered for filling up the smaller, and protecting the large one by damming it.

„ 12 —An old line intervenes between the great breach and a new one, taking off from Mohunpore to Bangamara, line objected to as too retired, having much land exposed, it is from being constructed in the rains, and left in an incomplete state; remarks upon the inadvisibility of constructing embankments in the rains as they have failed in every instance in the Burdwan Division, whilst those completed before it, have stood. The line to be strengthened and raised, excavation in front of bund to be dammed.

„ 13.—Country in rear of the embankment at Bangamara low, Sections of old and new line given, Section decreases at Joyrah, recommends it to be strengthened and improved

„ 14.—New line from Joyrah to Mohunbattee described, the continuous excavation in front to be dammed at inter-

vals. An embankment of small Section recommended where the line of bund ends.

PARA. 15.—North of Cooltigree to Chuckessub, bund insignificant and useless, a new line necessary; embankment improves from last-named village, but Section bad, line tortuous and approaches dangerously near the river, a new line to be formed in continuation, terminating at Nuskerpore.

" 16.—Old line between Nuskerpore and Champadanga to be repaired, strengthened and straightened, it is close to river and the river bank has been sloped off to prevent further cutting here, as well as at Pospore, lower down which has answered.

" 17.—A new line described below Champadanga to Comarchuck constructed before last rains, crest two feet lower than last season, no injury sustained except to some turfing, and notices the cause thereof, would have been more serviceable was it nearer the river, marsh on which it stands to be drained.

" 18.—Only small portion of embankment remains at Comarchuck as far as Morell, a new line in continuation in course of construction, the old line is dilapidated and tortuous, observed improvement in the system of embankment under construction, old line to Badoorchuck in good order.

" 19.—A new line commences from Badoorchuck constructed last season, requires raising two feet. At conclusion of part I. will be given an account of a guage to prevent the practice of working in the dark. Notices slight additions made to embankment, completed additions do not incorporate, and loss sustained thereby in turfing.

" 20.—At Bindaramchuck and Rompore bank of river partly sloped, and, with advantage, may be continued to a further extent. A re-entering angle under correction at the last-named village. Hurriarpore to Camarea Khal, the whole line remodelled, and that below Sinti having been done before last rains. Bank sloped from below Pospore with very good effect.

PARA. 21.—Abrupt termination of embankment quarter mile North of Camarea Khal, which is an outlet from the Damoodah into Mundorea Khal, it injuriously withdraws a portion of the flood waters, which here, and at the Canna, become the repository of silt from effects of diminished velocity. Dam ordered to be made across Camarea; abandonment of embankment on South bank recommended; embankment in the interval northward on the left bank of Damoodah to be continued.

„ 22.—Embankment lower down not cared for nor in so good order as the lines North of Camarea A Jheel below Gobindchuck slopes of the embankment to be extended and protected by stakes, suggests drainage of Jheel through iron pipes as it seriously affects stability of embankments.

„ 23.—From Naichuck to Callenchuck, line in a precarious position, it may be preserved by sloping bank of river during the rains, three huts on embankment to be purchased and removed, and the line kept free from such encumbrances. Below Callenchuck line further retired, was repaired and strengthened last year. Below this part at Singchuck the position similar to that at Naichuck, and similar means will be adopted for its preservation.

„ 24.—From Singchuck to junction of Mundorea Khal embankment scarcely exists, having been abandoned at the representation of Colonel Sage. Points out that Officer's error and states that the water required for raising that crop, may be obtained from sluices, and that the embankments of the Damoodah be kept up most strictly not only for protecting the country, but forcing the floods to scour the river bed. Recommends line from Singchuck to Mundorea being entirely remodelled, and assigns cause why the old line cannot be repaired, suggests that Civil Officer accompany the Executive Engineer, to visit the spot, and make over the land required for new line, as it will otherwise take half a season to survey and measure the parcels of land appertaining to different owners, and hence much valuable time will be lost.

PARA. 25.—To complete the protection, suggests that portion of the embankment from Burra Moira on left bank of Mundorea to the Bungalow at Omptah be straightened and remodelled.

„ 26.—Notices that Omptah is the limit of the effects of tides, river changes its nature there; above that point its bed is pure sand, and below it to its out-fall at the Hooghly is silt. No drainage falls into the Damoodah above Omptah, owing to high level of tract, but below it receives numerous muddy khals the drainage of low lands to the Hooghly, further notice will be taken of it in Part III.

„ 27.—From above Omptah to Doura, line in good order, between Doura and Rannapara, it is being strengthened, and repaired this year A breach from a sluice having blown up from faulty construction, and a channel formed to the river, proposes to dam it and put a new sluice in of better construction, sinuosities in the line requires strengthening and correction as far as a mile below Oudan.

„ 28 —At Coila commences the Depôt of the Bengal Coal Company, as far as Futtehpore, with other encumbrances which is brought prominently to notice. At Futtehpore there is a bazar occupying quarter of mile of the crest, and slopes of embankment, which should be watched to prevent further encroachments, and weakening of the line from abstraction of earth from it.

„ 29.—Remarks that the embankment from Noapara to Musraka are in the same state as when I last saw them in 1847, require remodelling and correction of alignment.

„ 30 to 37.—Reports on the embankment on right bank as far as Musraka Ghaut, the limit of the Burdwan Division, and points out the dilapidated state of the lines, the appearance of the country in consequence of neglect of embankments.

„ 38 to 51.—Reports on the right bank from Musraka to the Hooghly being in the Midnapore charge, points out

the inutility of the Government expenditure on their embankments if the zemindaree lines intervening and adjoining be not kept up in the same degree of efficiency. Notices how very badly the Darogahs have performed their duty in the repair of several lines, and in what a neglected state these embankments appear to have been kept.

PARA. 52 to 68 —Reports on the state of the embankments on left bank resumed from para. 29, notices as in the previous para. the little care that has hitherto been bestowed in the proper preservation of correct Sections or height of the embankments, how inefficient have been the repairs given last year, which demand strengthening and additions, this repeats the necessity of taking the zemindaree lines into our own hands, for reasons given, and the state of the lines as remarked on.

PART II.

1 Notices the ill-effects from retiring lines of embankments too far from the river margin.

2. Brings to notice the necessity for a revision of establishment and passing of an Act for the preservation of the embankments and notices the existing evils of the system at present.

3. Notices the instances and circumstances under which only should work be carried on during the rains.

4. European supervision shown to be preferable to Native.

5. Relative to the dams and sluices of tributary streams.

6. The sloping of the banks of rivers absolutely necessary for preservation of embankments and should be a part of the system.

7. Noticing that the correct flood-rise of rivers has not been registered or sufficiently accurately inquired into, and proposes a guage and register for the better correction and regulation of the same.

8. Gives the reasons for neglect of the embankments by the zemindars.

9. States that the remarks on the embankments will be forwarded to the Officers concerned.

Part III.

1. Effect of inundating rivers as regards the deposit of the sediment on the margin, and gradual decrease with the distance from the river bank.

2. The Damoodah follows the law of all inundating rivers and points out that the Damoodah is on a much higher level than Roopnaram

3. Proves that the Roopnaram and not the Damoodah is the cause of the formation of the sands in the Hooghly called "the James and Mary," with diagram to illustrate the same.

4. The contraction of the river channel limits would have the effect of scouring the bed and not that of forming sands and shoals as supposed by Major Baker.

5. The embankment Sections are more than equal to the greatest pressure of water, as shown in para. 10 Part I., and sand has only been deposited in those parts where lateral channels have drawn off part of flood water.

6. The velocity of Damoodah during any other season but the freshes, is not sufficient to transport sand, and that it is only during that season that debris is carried on to the Hooghly.

7. Shows that an attempt to prove that the Damoodah bed was silting up is fallacious, and that by the maintenance of embankments on both banks the bed will be scoured out instead of being encumbered.

8 Proof of above with diagram.

9. Further proof, referring to the rivers where the narrower bed admits the passage of floods, without erosion, and that where there is lateral expansion the banks are eaten away.

10. The advantages and power to be gained in scouring the bed, by the admission of the volume of water that Major Baker says passes through the channel in flood.

11. The effect of limiting the flood is to increase the velocity and not to raise the level of the water.

12 Refers to the examples of former times—the silting of the Euphrates and Tiber from the effects of withdrawing portion of water; and shows that from the calcareous nature of deposit the "Lamone" a tributary of the "Po" in Italy, had its bed raised and that this has no reference to the Damoodah. Other examples and authors quoted in proof of truth of para. 11.

13. Recapitulation of three foregoing truths.

14. Arguments against the proposal brought forward for the abolition of the embankments on right bank.

15. Explains an apparent error regarding the effects of a breach at the village of Bangamara.

16. The cost of remodelling the embankment on right bank would not be more than the proposition for a central embankment between the Damoodah and Roopnarain.

17. Reference to sheet of Sections showing the glacis of the marginal deposit, sloping towards the interior.

18. Reference showing where and under what circumstances sand deposit has occurred; and points to those channels where high banks have passed the whole flood water and scoured the channel's bed.

19. Points to the Sections below limit of tides to show that the floods have a clear exit.

20. The fallacious system on which the embankments have been hitherto maintained has been the cause of disasters and loss of money, and points to the evidence in favor of the new system and maintenance of embankments in all their integrity.

H. GOODWYN, *Lieut.-Col.*,
Superintending Engineer, S. E. Provinces.

No 536.

FROM

LIEUT.-COL. H. GOODWYN,

Superintending Engineer, S. E. Provinces,

TO

LIEUTENANT J P. BEADLE,

Officiating Secretary, Military Board.

Calcutta, 25th May, 1853.

SIR,

WITH reference to the orders of the Military Board, No 13,766 of 28th ultimo, that the course of a nullah opposite to Selimpore on left bank of Damoodah, should be traced towards the Dalkissore, under the idea that an artificial junction might be made to carry off part of the Damoodah floods, I have the honor to forward a report from Lieut. De Bourbel on the subject, accompanied by a sketch I think that this Officer has done all that is possible this season owing to the impracticable nature of the country, and the impossibility of effecting a clearance sufficient for levelling purposes before the rains.

2nd. As regards the probable effect, I cannot but reason consistently with my former opinion that it would be injurious to the future state of the river itself.

I have, &c,

(Signed) H GOODWYN, *Lieut.-Col,*

Superintending Engineer, S E Provinces

REPORT ON A KHAL PROPOSED TO BE MADE FROM THE DAMOODAH TO THE DALKISSORE RIVER.

THE Buddye is a large nullah (*vide* sketch) which branches off a little below Selimpore, from the right bank of the Damoodah River in a southerly direction for about two and half miles, and then continues its course parallel to the Damoodah for four miles, where being turned off to the North by high ground, it is divided into two channels, one of which

falls into the Damoodah at Panchpara, the other being joined by the Selye Nullah also discharges itself into the Damoodah lower down at Soomsur. Should the khal be made therefore from the Buddye Nullah to the Dalkissore, it would save two-and-half miles of excavation, and receive the Damoodah floods.

2nd. The Dalkissore River having its course nearly parallel to the Damoodah, is distant from the latter about 15 miles, at Palla however taking a curve to the North, it reaches to a distance of 12 miles from the Damoodah. I found a nullah here which falls into the Dalkissore, and tracing its course in a north-west direction for seven miles, arrived at Dominy, from whence it is an insignificant brook for three miles up to Ranee, its source, situated in a dense jungle.

Dominy is four-and-half miles distant from the Buddye and Ranee about five miles. Should the khal be made therefore from the Buddye to meet the above nullah, it would save five miles of excavation.

3rd. To make a cut direct from the Buddye to meet the nullah at Dominy would be a very expensive undertaking, as it must pass through the high ground at Kistenuggur which is on an average 100 feet above the level of the bed of the River Damoodah. But as there is lower ground in the jungle to the West of Kistenuggur dotted with some high mounds, a khal might be made starting from the Buddye, avoiding these high mounds to fall into the nullah between Ranee and Dominy. This khal would have to cross the Selye Nullah mentioned in paragraph (1) which has its source from near Bancoorah, it will be requisite therefore to turn off the course of this stream into the Dalkissore.

4th I found it impossible to take levels during the hot weather, as greater part of the work would be in a dense jungle 10 feet high, and to carry lines of levels through this it would be requisite to employ a number of men and elephants to cut the trees and brushwood away in order to form a clear road.

(Signed) R. DE BOURBEL, *Lieutenant,*
Executive Engineer, 17th Division, in Charge

(True Copies)

J. P. BEADLE, *Officiating Secretary*

No. 1437.

FROM

LIEUT.-COL. H. GOODWYN,
Superintending Engineer, S. E. Provinces,

To

LIEUTENANT J P. BEADLE,
Officiating Secretary, Military Board.

Calcutta, 13th July, 1853.

SIR,

Burdwan Division

I HAVE the honor to forward the sketch map of the survey and levels between the Rivers Damoodah and Roopnarain taken by Lieutenant Stewart de Bourbel and Mr. Nield during last cold weather, together with a report on the result of their operations.

2nd. There are several important facts to be noted from this survey, amongst the principal are, *first*, that the ridge or high tract which was supposed to exist between the two rivers terminates in a line drawn from Burdwan to Kunderlie on the Dalkissore, or about one-fifth of the whole length between the extremes of the survey.

Secondly.—That the level of the bed of the Roopnarain is considerably below that of the Damoodah.

Thirdly—That there exists a tract from below the Calcutta and Bancoorah road, 30 miles above Omptah, where the intervening country is from 6 feet to 11 feet below the flood-level of the Domoodah, whilst above that road, in the vicinity of the right bank of the Damoodah, there are many spots below the level of the highest floods, as shown by the difference between the blue and red figures, the flood-rise being at least 17 feet.

3rd. It would be superfluous for me to reiterate my opinions and to urge the strong reasons which I before gave for keeping up in strict integrity the embankments on the right bank of the Damoodah, which, as I before stated, involves another beneficial result than that of protection to the country, *viz.*, that of vast improvement to the river itself, and the gradual lowering of its bed.

4th. Any attempt to form a central line of embankment between the two rivers will be attended with the disastrous effects of forming an unhealthy marsh in the interior, as the margin of the river will rise as each successive flood goes over it in far greater proportion than any other spot distant from it, and the present waste and desolate tract of 60 square miles will be increased tenfold. I again request consideration to Part III. of my report, and hope that the arguments may be duly weighed before the determination is come to.

5th I would claim some credit for the young Officers who have drawn up the report, as they have evidently, zealously and critically noted the peculiarities of the country, with a view to general utility. The kunkur formation may possibly be valuable and is worthy of further inquiry.

6th. I have kept no copy of either report or sketch, knowing that they were required without delay, so that I trust they will be returned to be recorded in this office.

I have the honor to be,
Sir,
Your obedient Servant,

H. GOODWYN, *Lieut.-Colonel,*
Superintending Engineer, S. E. Provinces.

REPORT ON THE SURVEY AND LEVELS TAKEN IN THE COUNTRY SITUATED BETWEEN THE DAMOODAH AND ROOPNARAIN RIVERS, 1852-53.

EXTENT AND BOUNDARIES.—The whole tract surveyed and levelled in the cold season 1852-53, in extent 1,400 square miles, and situated on the southern portion of the Burdwan division in Bengal, is bounded on the North and East by the Damoodah River, on the South by a cross-line from Omptah, on the left bank of the Damoodah (aligned on Midnapore) to Bathara on left bank of Roopnarain River, and on the South-west and West by the Dalkissore or Roopnarain River, and a cross-line from Panchpara on the right bank of Damoodah (20 miles West of Burdwan) running in a southerly direction to Jaguldeep on the left bank of the Dalkissore River.

This tract was divided into three portions.

No. I. containing 400 square miles, extends East from the cross-line between Panchpara and Jaguldeep to the Burdwan and Midnapore road, which, starting from Burdwan in a southerly direction, crosses the Dalkissore River at Aclochy. This part was surveyed and levelled by Lieutenant Stewart, Bengal Engineers.

No II. containing 600 square miles, extends East and South from the Burdwan and Midnapore road to the Calcutta and Bancoorah road, which crossing the Damoodah River at Serampore runs in a westerly direction to Jehanabad on the Dalkissore River. This part was allotted to Lieutenant R. de Bourbel, Bengal Engineers.

No. III. containing 400 square miles, extends South from the Calcutta and Bancoorah road to the cross-line between Omptah and Bathara This part was surveyed and levelled by Mr. Nield, Surveyor

GEOLOGICAL FORMATION.—The large bed of gneiss in Bengal appears to terminate near the cross-line between Panchpara and Juguldeep, thence the whole tract consists of an alluvial deposit with a subsoil of tenacious clay mixed with large quantities of ghooting, varying in thickness from 10 to 30 feet, with a slight dip to the South-east, beneath this is found green sand or other diluvial deposit.

CULTIVATION.—The banks of the Damoodah and Dalkissore Rivers yield in great quantity and perfection, indigo, tobacco, potatoes, mulberries, plantains, melons and various kinds of fruit trees.

In portion No. I., rice of a moderate quality is produced, and in No. II and upper part of No. III., rice and sugar of the finest quality are obtained, owing in great measure to the retention of water by the tenacious subsoil, and to this cause, together with the want of natural drainage, may be ascribed the existence of extensive swamps and marshes in the lower part of No. III. portion, which, however, yields in the hot weather the finest pasturage.

ASPECT AND CONDITION OF THE COUNTRY.—The traces of numerous fine roads, the ruins of large villages, and also houses, the fine temples still existing, and principally the enormous tanks, the remains of which may be still observed, all attest the former traffic, wealth, and prosperity of the people of this district. It contains still many populous villages, the most considerable of which are, *viz.*,

In No. I. Kistenuggur, Balsee, Indoss, Soonda and Kundghose

In No. II. Royna, Kytee Chundoor, Jehanabad, where a Deputy Magistrate resides, Myapore, where great quantity of silk cloth is manufactured, Kesubpore, Moloepore, Gothan, Bangamara and Sadepore.

And in No. III. Balee, Ghosepore, Guttal, Joypore, Durgapore, Kishnuggur, Khanakool and Omptah.

In consequence of the inundations which have spread over the country from the breaches in the embankments on the right bank of Damoodah river, large tracts of land (total extent 60 square miles,) are now uncultivated and lying waste, and in the lower part of No. III. portion extensive marshes are formed, whereby land is much deteriorated and is reduced from 80 to 95 per cent. of its value.

The population of the whole district may be taken at 1,20,000 inhabitants.

The principal roads are, Calcutta and Bancoorah road) All these
Burdwan and Midnapore, ... „) roads much
Ditto and Myapore, ... „) dilapidated, in
Ditto and Jamalpore, ... „) many cases so
Ditto and Jehanabad, ... „) encroached

upon by the zemindars, as to be reduced to the single bund of a rice field.

The Calcutta and Bancoorah road is now being repaired by the Deputy Magistrate of Jehanabad.

Levels of this District as compared with the beds of the Damoodah and Roopnarain Rivers.

In order to ascertain the levels of this district, cross-lines, about seven miles apart, were taken from the Damoodah to the Dalkissore or Roopnarain river, and longitudinal lines six miles apart were taken on and parallel to the banks of these two rivers At every point of intersection pucca bench marks have been kept and noted down taking the low water mark of the river Hooghly* at 100 feet for a datum level.

Damoodah River.

In annexed plan this river begins about 20 miles West of Burdwan, running due East for 34 miles, averaging one mile in width, with a fall of 1 3 [2 3?] feet per mile. When meeting higher ground, or owing to some geological feature, its course turns to the South for 56 miles, averaging half mile in width or even less, with a fall of 1·1 feet per mile. The

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* This is a mistake The datum is that of Lieut. Piele and Johnston's Survey, the top step of the ghaut at Bydabattee, 29 4 feet above low water

banks of this river average ten feet in height, (at Omptah they are 15 feet,) the floods rise from 14 to 16 feet above the level of the dry weather stream, and the tide runs up to a little above Omptah.

The Dalkissore or Roopnarain River.

In annexed plan the Dalkissore river runs from Jaguldeep with a very winding course towards the South-east for 22 miles, averaging half a mile in width, with a fall of 2 2 feet per mile. When turning South and changing its name to that of Roopnaram, it runs for 24 miles, averaging a quarter of a mile in width, with a fall of 1·3 feet per mile.

The banks of this river are 19 feet high, the floods rise from 14 to 16 feet in height, and the tide runs up 20 miles above Bathara.

The right bank of the Damoodah river is a few feet above the level of the tract in its vicinity, from thence the ground rises towards the interior, forming a ridge situated midway between the two rivers, and afterwards falls gradually to the left bank of the Dalkissore river.

This ridge at the West end of the survey is 43 feet above the bed of the Damoodah and 68 feet above the bed of the Dalkissore, making a difference of 25 feet between the levels of the two rivers. At the Burdwan and Midnapore road, it is 21 feet above the bed of the Damoodah and 68 feet above the bed of the Dalkissore, thus giving a difference of 28 feet between the two rivers. From this point the ridge may be said to terminate and the country gradually falls, till on the Calcutta and Bancoorah road, it is only ten feet above the beds of the two rivers which here are on the same level owing to the Damoodah traversing 50 miles while the Dalkissore only flows ten miles of its course.

Below this road the country is flat, and at the cross-line between Omptah and Gopeegunge it is five feet higher than the bed of the Damoodah river, which at this point is four feet higher than the bed of the Roopnaram.

Natural Drainage Channels.—In the low tract five miles in width situated in the vicinity of the right bank of the Damoodah there are several nullahs, some of which are large and deep, especially the Bachoordah and Singar Khals These flow down this tract in a course parallel to the Damoodah as far as the Calcutta and Bancoorah road, where being joined by the Canna Nuddee and the Moondasuree Khal, the former of which flows from the Dalkissore river below Chandoor, and the latter (having its source at the termination of the ridge near Ochallun on the Burdwan and Midnapore road) flows in a South-easterly direction,

they spread themselves like a net-work over the country, and for want of a sufficient fall to carry off the water they form in great measure those extensive marshes situated at the South end of the survey.

Were the floods of the Damoodah to range freely over the whole of this district the water would flow down the above tract (this has always been the case when breaches have occurred) as far as the Calcutta and Bancoorah road, when it would spread itself unchecked over the whole country (an extent of 400 square miles) and then finally after filling up all the hollows would pass into the Roopnaram.

Embanked Roadway from Omptah to Bathara.

Previous to any embankment being raised it is obvious that the extensive marshes on the proposed line must be well drained, this can be effected by surface draining into the Roopnaram river alone, but would involve an expenditure of not less than Rupees 50,000. Deep draining might be resorted to with advantage by sinking deep shafts or boring through the tenacious clay (forming the subsoil) into the bed of sand beneath, which if not already saturated would drain off the whole of this district in a very short time.

The expense of constructing this embanked roadway 30 feet broad, average height 18 feet, and slopes 5 to 1, would be Rupees 15,000 a mile, making a total of Rupees 1,50,000.

An embankment constructed midway between the two rivers and parallel to their course, if carried up to the Burdwan and Midnapore road, would be 40 miles in length, its height would average 10 feet, breadth at top six feet, and slopes 5 to 1, and cost Rupees 6,000 per mile. But as the Dalkissore River as far as 12 miles below Jehanabad does not overflow its banks, except in very high floods (the last of which took place in 1830, when the combined floods of the Damoodah and the Dalkissore swept over the whole district below the Burdwan and Midnapore road) this embankment if constructed would have only to restrain the floods of the Damoodah, thereby causing this river to form a new course which would pass down the low tract through which the Bachoordah and Singar Khals now flow.

This new course would act as an escape to the Damoodah, and were this the purpose in view together with the protection of the Mundleghat estates, numerous cuts might be excavated to carry off the waters of the

Damoodah into the above khals, the whole to fall into a canal carried (in a South-west direction) in continuation of the Damoodah Khal (which flows from the Damoodah River at Golah) to join the Canna Nuddee at Paluspai, and thence to flow into the Roopnarain below Maralhana, (this would only give an excavation of four miles to join the Damoodah Khal and Canna Nuddee) the whole length of the canal would be 18 miles, with a fall of 1 3 feet per mile, and if an embankment 16 feet high, with slopes 5 and 3 to 1 and ten feet broad at top, were raised on the South side of the canal, it would effectually protect the Mundleghat estates, from being flooded.

This however is only one of the great number of escapes that could be formed to carry off the waters of the Damoodah into the Roopnaraın by taking advantage of the numerous khals which lie to the South of the Calcutta and Bancoorah road, and giving to every canal a South-west direction in order to secure a sufficient fall.

Whatever effect these canals may have in reducing the floods of the Damoodah and increasing those of the Roopnaraın, one great advantage would accrue to the people of this lower district, that of thoroughly draining the whole tract, and thereby enabling the inhabitants to cultivate it, and to restore to the land its former value.

R. DE BOURBEL, *Lieutenant,*

Officiating Ex-Engineer, 17th Division.

BURDWAN, *9th July* 1853.

MEMORANDUM ON THE SURVEY OF THE DAMOODAH AND QUESTION OF THE ABANDONMENT OF BUNDS ON THE RIGHT BANK TO ACCOMPANY THE MAP RECEIVED WITH SUPERINTENDING ENGINEER SOUTH-EASTERN PROVINCE'S LETTER No 1473 OF 13TH JULY 1853.

I. Capacity of the Damoodah Channel.

THE Board have for some time been in possession of a set of transverse Sections of the upper parts of the Damoodah Channel (in the Burdwan District) taken by Lieut. Russell, and more recently a set taken lower down the stream was furnished by Lieut. Colonel Goodwyn with his Inspection Report dated 10th February 1853. These Sections indicate

a gradual diminution of capacity of the channel in proceeding from the high to the low lands,* but as there was no line of levels down the stream, the declivity of the river's bed could not be stated with certainty, and therefore the capacity of the channel to carry off the floods remained in some degree undetermined.

2. The information wanting has now been supplied in the survey before the Board, and the Section down the stream of the Damoodah will be found amongst the sheets of Sections which have been compiled from the survey. Two cross Sections of the lower part of the river have also been obtained from the Surveyor Mr. Nield, and added to the papers.

3. In calculating the quantity of water passed off by the river channel at the points where the Sections have been taken, the velocity of the stream has been determined by the formula of Eytelwein, which is that generally preferred for application to the movement of large bodies of water, namely—

If f be the fall of the stream in feet per mile,

d, the hydraulic mean depth (or fraction $\frac{\text{area of transverse Section}}{\text{length of line of contact with water}}$) in feet.

(The geometrical mean depth has been used in this paper as sufficiently accurate for channels generally of great width)

v, the mean velocity in feet per second,

then

$$v = \tfrac{2}{10}\sqrt{2fd}$$

4. In the following table of results the "fall per mile" has been calculated from the nearest levels of the bed of the channel on the longitudinal Section above adverted to.

5. The "mean depth" and "area" are taken with reference to assumed flood levels, which are indicated on the transverse Sections as well as on the longitudinal Section. The assumptions are made from comparison with the height of the bunds, with the flood-level of Colonel Goodwyn's Sections (ascertained as nearly as possible from inquiry on the spot), and from the old Sections by Captain de Bude, and the account of the flood of 1840 in Captain Finnis's Journal, and from the Sections given in Colonel Sage's Inspection Report after the flood of 1845.

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* See also Major Baker's Memorandum, page 88, para. 19, Selections, Bengal Government Record, No. XII.

Table showing the Capacity of the Damoodah Channel.

No	Description and place of the Section.	Distance above or below Burdwan.	Width of flood stream, bund to bund in feet	Area of transverse section in square feet.	Mean depth at flood.	Fall of bed in feet per mile	Mean velocity in feet per second.	Discharge in cubic feet per second.
		above miles	feet					
1	Lieut Russell's Section No 1 at Ameerpore, above junction of the Buddye Nullah but includes it,	22	8,891	85,393	9 56	3 (?)	6 8	580,672
2	Ditto ditto No 2 at Bikrampore, (includes Buddye Nullah,)	16½	13,398	103,917	7 74	2 5	5 6	581,935
3	Ditto ditto No 3 at Rugubpore,	6½	6,910	81,631	11 8	1 95	6 1	497,949
4	Lieut.-Col Goodwyn's, No 2, Burdwan,... .	0	4,950	49,624	10 0	1 6	5 1	253,082
		below						
5	No 3, Selalpore, .	12	3,000	28,716	9 5	2 1	5 7	163,681
6	No 5, Culna, .	19½	975	16,439	16 9	2 2	7 7	126,578
7	No 7, Santospore,	30	1,005	18,719	18 6	1 0	5 5	102,954
8	Mr Nield's No 1, Serampore,	35	2,060	21,186	10 3	1 2	4 5	95,237
9	No 2, Omptah, .	55½	2,220	22,505	10 1	0 7	3 8	76,519

N B —At Omptah the river begins to be tidal, the tide at spring raising the dry season stream about 1 or 1½ feet The level of this rise being still 14½ feet below the surface level in floods, it is not supposed that the tides will affect the flood stream at Omptah below the channel is more capacious

6. From this table it appears that the maximum flood discharge of the Damoodah is about 600,000 cubic feet per second in the upper part of the river, a result which very nearly agrees with Major Baker's calculation* from the probable effect of a heavy fall of rain. He reckoned upon 645,833 cubic feet per second.

7. As the stream proceeds on its course, it further appears that the capacity of the channel diminishes, and by the time it reaches Omptah the river will not carry off much more than one-eighth part of the water which flows from above.

* Selections Records Bengal Government, No. XII page 85.

8. This shows the insufficiency of the Damoodah as a channel for carrying off heavy floods. Considering it as a basin for receiving them its content will be found as follows:—

	Miles.	*Areas in feet.*	*Products.*
Between Section 1 and 2 —	$5\frac{1}{2}$ ×	$\frac{83,393 + 103,917}{2}$ =	520,602
2 and 3 —	10 ×	$\frac{103,917 + 81,631}{2}$ =	927,740
3 and 4 —	$6\frac{1}{2}$ ×	$\frac{81,631 + 49,624}{2}$ =	426,530
4 and 5 —	12 ×	$\frac{49,624 + 28,716}{2}$ =	470,040
5 and 6 —	$7\frac{1}{2}$ ×	$\frac{28,716 + 16,493}{2}$ =	169,751
6 and 7 —	$10\frac{1}{2}$ ×	$\frac{16,439 + 18,719}{2}$ =	185,104
7 and 8 —	5 ×	$\frac{18,719 + 21,186}{2}$ =	99,763
8 and 9 —	$20\frac{1}{2}$ ×	$\frac{21,186 + 22,506}{2}$ =	447,832
			3,247,412

3,247,412 × 5,280 = 16,988,035,360 cubic feet or equal to 8 hours' discharge of 600,000 cubic feet per second

9. Making full allowance for the errors to which inferences based on calculations of this nature are liable, these figures appear to authorize the conclusion that the Damoodah Channel filled up to the top of the bunds* will not contain more than 9 or 10 hours' discharge of its heaviest floods, and that when full the lower part of the channel will not carry off more than one-sixth part of what flows in from above. It follows that if a full flood last more than 9 or 10 hours the bunds must be topped and burst, and that the maintenance of complete lines of bunds on their present sites and of their present dimensions during heavy floods is impossible.

II. Comparison of the foregoing Results with the account of the great flood of 1840, *&c.*

10. No breach is recorded by Captain Finnis to have occurred in 1840 above Singutgolah. It may be assumed therefore that the floods in the

12 miles above Burdwan

* *Vide* flood lines on cross Sections

upper part of the river did not top the bunds. In assuming the flood level of the first Section level with the top of the bunds a full maximum has been allowed for the flood discharge.

23½ miles above Burdwan

11. The second Section still allows the full flood to pass, and is also above any recorded breach.

18 miles above Burdwan

12. Going on to the third Section at Rugubpore the flood discharge is found to be reduced by about 100,000 cubic feet per second, and accordingly it is recorded that in 1840, 18 breaches occurred just above the third Section, although the bunds on the right bank are not continuous

8 miles above Burdwan

13. At the fourth Section, opposite Burdwan, the discharge of the channel is further reduced by 250,000 cubic feet per second, and in 1840, 27 breaches occurred between Rugubpore and Burdwan, notwithstanding that the bunds on the right bank are discontinuous and weak in section.

14. Between Burdwan and Selalpore, the discharge of the channel reduces by 90,000 cubic feet per second, and in 1840, 32 breaches occurred here.

15. The channel further reduces by the capacity to discharge 37,000 cubic feet per second between this and Culna, and seven breaches occurred in the intermediate space, the head of the Canna Nuddee also being there, but on the Nuddee head there appears to have been not more than 1½ or 2 feet of water.

16. Between Culna and Santospore, the channel diminishes by the capacity to discharge 24,000 cubic feet per second. In this part occurred only the great breach at Bungamara, said at one time to have carried off as much water as the river itself.

17. From this to Serampore were four breaches; it will be seen that the Sections show a diminution of only 7,700 cubic feet in the discharge of the channel

18. Between Serampore and Omptah, the channel diminishes by the capacity to discharge 19,000 cubic feet per second, and 28 breaches are recorded in this part in 1840, all about (above and below) the head of the Damoodah Khal.

19. Making allowance for the occurrence of many breaches, merely from defects in the bunds, this comparison appears sufficiently to indicate that the breaching of the bunds in 1840 was principally due to the

diminution of the capacity of the Damoodah channel in passing from Sungutgolah to Omptah, and that this diminution is on the whole correctly shown by the foregoing calculations.

20. There is not a complete list of the breaches of the flood of 1845 in the Office, but it seems from the reports that in that year more breaches took place above Joojooty, and some even up to the highest Section of Lieut. Russell's survey, but the flood was not so high as the bunds at the points where the Sections are taken.

III. On the rise of the Damoodah bed.

21. The first two cross Sections of the country show that the Damoodah in that part of its course, so far as the right bank is concerned, occupies the lowest part of the country through which it flows, and excepting the low land between the river and Buddye Nullah, would not flood the country to any considerable extent, even if there were no bunds.

22. At Joojooty and Burdwan the Sections show that much of the country would, but for bunds, be inundated in high floods, but still the river channel is so situated that the water would return quickly to it on the cessation of the floods. This does not hold good of the left bank. The country on that side is lower than the river from Joojooty downwards, and all flood-water escaping on the left passes down the Banka Nullah and never returns to the Damoodah.

23. Below Burdwan, on the right bank, the relative levels of the country and river change. The lowest land on the Futtehpore and Sanipore Sections is not five feet above the bottom of the Damoodah channel. On the Bistopore and Calcapore Sections the difference is greater, being 8 and 7 feet, but below these, the lowest point of the country is very little, and in some places not at all, raised above the bed of the river.

24. In the lower part of its course, where the channel is narrow, the river bed appears to have risen greatly since the stream first occupied its present course.

25. No rise of the bed, however, can be ascertained to have taken place of late years.

The Section, taken by the late Captain De Bude at Burdwan in 1837, shows precisely the same maximum and mean depth as the present Section, measuring the flood-rise from the level of the ground at the same distance in both Sections from the river's bank. The Section taken at Culna, shows that the mean depth of the river at that place has increased by about three feet, the maximum depth remaining the same.

This shows no rise, but on the contrary a scouring out of the river bed. The Section taken at Bungamara is not sufficiently near to any of the recent Sections to admit of comparison.

26. It must, however, be remarked that the ground inside (on the land side) of the bunds, from which the heights are measured, 3 or 400 feet from the bank of the river, appears to have risen (with the bed of the river) as it is stated to have done in Mr. Drummond's report.* The bench marks of the Sections should have been accurately described to make a satisfactory future comparison possible.

27. It is further to be noticed that the Canna Nuddee, which formerly carried of a large portion of the floods, has for some years been silted up, and has been dammed across lately. And lower down, near Serampore, too, a change has taken place. The present channel of the Damoodah was called the Biscallee River, and what is now called the Damoodah Khal was the Damoodah River. At the time of Captain Bell's inspection in 1835-36, the Biscallee was the largest river of the two. Now it is the main stream and the former Damoodah is a mere khal.

28. These variations appear to point out that the deepening of the channel at Culna, (perhaps also at Bungamara) may be the temporary effect of other changes.

29 There are no copies in the Office of the Sections quoted in the printed report of the Embankment Committee of 1846, and the statements there are not sufficiently precise to admit of comparison with the present survey.

IV. Statement of the proposal to improve the Damoodah by closing in the bunds and so increasing the scour.

30. The velocity with which water flows is known to depend equally (or nearly equally) upon the rate of declivity of the stream and its mean depth.

31. From the way in which the plains have been formed by the degradation of the high lands, principally by means of the flow of rain-water into the sea, the land has generally a greater declivity in its upper parts than towards the sea. This variation in the rate of declivity is generally shared by the rivers, which consequently have a more rapid fall in the upper, than in the lower parts of their courses. Hence the velocity of rivers, if they do not increase in depth as they flow towards the sea, must suffer more or less gradual diminution; and as the velocity (other

* Para. 9, page 24, of the XIIth No of the Selections, Bengal Government

things being equal*) determines the quantity of suspended matter the water carries, rivers which do not increase in depth in proportion to their decrease in declivity must deposit the matter which their impetus is no longer sufficient to carry forward in those parts of their beds where the reduction of velocity takes place, and the beds will therefore rise.

32. But on the other hand, if the depth increases as the declivity is reduced, the velocity may remain the same, and, for so much of its course as this relation holds, the stream will carry off all the suspended matter, and the bed will not rise because there will be no deposit to raise it. Such a state of things, however, cannot be permanent. The suspended matter will be finally carried out and deposited at the mouth of the river, it will gradually form new land there, and lengthen the river's course, without increasing the difference of level between the highest and lowest parts of the channel; and increase of length without proportional increase of height or depth is reduction in declivity. All river beds therefore must ultimately rise, though the process may, in some cases in which the mean depth and declivity have once been adjusted to an uniform velocity, or to a variable velocity adapted to the nature of the soil in different parts of the stream, be exceedingly slow; so that except in particular parts of the stream it is unimportant in Engineering operations.

33 From these principles it follows, that a river having a nearly uniform width, and receiving tributaries as it proceeds on its course, may, although its rate of declivity is constantly on the decrease, yet have its mean depth from time to time so augmented by the accession of the waters of the tributary streams, that its velocity may not be materially altered, and thus the circumstance of the accession of tributaries is found, in some cases, to obviate the tendency of a river's bed to rise, except by virtue of the slow lengthening of its course before spoken of.

34. Copying from Nature the Italian Engineers have by uniting streams hindered the rise of the beds of some of their rivers. On the same principles also, rivers have been improved, and the rise of their beds not only prevented but their channels scoured out and deepened by restricting their width, and so increasing their mean depth and consequently their velocity.

35. It is by this process that the Superintending Engineer South-Eastern Provinces proposes to improve the channel of the Damoodah so as to enable it to contain and carry off the floods between its embank-

* The effect of the nature of the soil is not for the present taken into consideration.

ments. The instances he quotes show that such a mode of proceeding has been very advantageous in many cases. Perhaps the most striking instance of the efficacy of such measures is the Clyde, which 100 years ago had in some places below Glasgow a depth of less than two feet at low water in the summer, while now vessels drawing 18 and 19 feet of water pass up and down the river at all seasons, and a depth of 10 feet at low water is maintained throughout.* This improvement, however, was partly brought about by dredging. (See a recent No. of Civil Engineer and Architect's Journal.)

36. The effect of an increased scour however is not always to improve a stream for navigation. D'Aubnisson mentions the case of the Robine canal near Narbonne which was originally made, purposely, with great windings and very small declivity, in order that it might have a slack current and deep water for the purpose of easy navigation up and down stream. Not perceiving the object of the windings, some persons afterwards proposed and carried out a straightening of the channel with the view of shortening the navigation This of course increased the declivity and the velocity of the stream, and the consequence was, that it became necessary to increase the supply of water and to establish locks to retain the canal sufficiently deep for navigation. This instance is not in point in the present case, (where the object is to increase the discharge, not the depth of water) except as showing the necessity in all such operations of attending to the declivity of the channel as well as its shape of section.

37. The Western Jumna Canal appears to be a case more in point. Its fall is pretty uniform, and the supply of water has been increased by about five times since 1829. The result of this enormous increase of volume (and of mean depth) has not been to scour the bed, for the foundations of the bridges remain undisturbed. It has raised the surface level of the water five or six feet, and in many places the bed also has risen. The deposit of silt in the channel has to be met by frequent clearances, as the Board are aware. In an irrigation canal, however, in which the water is constantly drawn off for the use of the crops, we have a case opposite to that of a river receiving tributaries in which the volume of water is constantly increased. The deposit of silt would probably be prevented if the declivity of the channel were made to increase in

* The improvement of the Clyde however which it has taken 100 years to effect, is but a small task compared with the improvement of the Damoodah, which is three times the length and drains eight times the area, and which discharges in great floods eighteen times as much water per seconds as the Clyde in its highest *spates*.

proportion as the volume of water, or rather the mean depth, suffered diminution. For the Damoodah, however, this instance is very much to the point, for the channel of this river has been shown to contract greatly in proceeding from Joojooty downwards. The instance at least shows that increase of volume of discharge or mean depth will not produce a scour when applied to cases in which other circumstances are unfavourable.

38. Another excellent lesson on this subject is afforded by the Eastern Jumna Canal.* As originally re-constructed, it had a greater slope in its upper parts, in a portion of which it flows through a light sandy soil, than in its middle part. A scour consequently took place in the upper portion, which carried down sand and silt which was deposited in the central portion of the canal where the slope was less, and so the bed of the canal was raised to such a degree that unhealthy swamps were formed by the percolation of water through the embankments. The remedy applied by Colonel Cautley was to reduce the declivity in the upper part by constructing masonry falls (by which the slope was cut down into steps) and when this had been done, the rising of the bed of the central portion of the canal ceased, and the excess of silt even gradually disappeared from many portions of the channel. This case shows that it is not enough in designing plans for the improvement of water-courses to consider the slope of the Section of channel and the declivity merely for the portion to be operated upon, but that remedies must be applied with reference to the soil and declivity of the channel above.

39. Besides the circumstances brought forward in these cases, there is to be considered the effect of that very important feature in the Damoodah, its liability to violent floods and the very small discharge of water it has in the dry season, which circumstances are due to the river being supplied almost entirely by surface drainage. After heavy falls of rain, it rapidly fills with water turbid with the matter swept off the high land drained into it. With the subsiding floods much of the solid matter is deposited as the current slackens, and after the rainy season is over no sufficient discharge of clear water remains to remove the deposits which the floods have brought down. It seems therefore that a river subject to such floods as the Damoodah is, requires on this account different treatment from what would answer in more uniform streams, to prevent a rise of the bed, if indeed it can be prevented at all.

40. Before considering any further the projects for improving the Damoodah, or mitigating the damage done by its floods, it seems therefore

* See Lieutt Morton's Printed Memorandum.

necessary to enter fully upon the circumstances of this river in all its parts in regard to its declivity, the soil of its bed, and the source of its supply, and the effect of these on the section and capacity of its channel. And first it may be well to state in general terms the different actions to which river channels are subject.

V. Some General Consideration of the Action of Water on the soil of its Channel.

41 If water be poured out upon the surface of a country having more or less declivity, one of three cases must happen.

I. The declivity may be such that the velocity produced will be sufficient to stir up the soil in every part touched by the water. In this case the quantity of earthy matter taken up by the water, where it is in contact with the soil, will be so great as to impair its fluidity. Its movement will therefore be retarded by this cause in addition to the friction of the bed. If the depth of water be great, the friction of the bed will be a small cause of resistance compared with the working up of the soil If the depth be exceedingly small, the working up of the soil will be a trifling resistance compared with the friction of the bed Either cause of resistance carried to extremity would stop the current, and it follows that there must be between the two extremes a certain depth of water at which the combined effect of the two sources of resistance will be a minimum This depth the stream will assume in virtue of the mechanical law of least resistance.

42. The form of least resistance once assumed, if the declivity of the stream be increased, the velocity will increase also, and will augment the stirring action on the soil. The relation of least resistance will thus be disturbed, and a preponderance given to the stirring action, the increment of which will therefore gradually reduce to a certain extent in consequence of a corresponding increment of the friction, that is by a reduction in depth.

43. When the current is strong enough to stir the soil, therefore, increase in the declivity of the stream causes a reduction in depth and consequently increase in width.

44. The consequence, in rivers, of great declivity relatively to the power of the soil to withstand scour is therefore a wide and comparatively shallow channel.

45. This is not meant to account altogether for the wide and shallow channels as they appear when empty after a flood has ceased, for in that

state their depth has been still further reduced by the deposit the flood leaves in subsiding. The actual channel afforded to a second flood of equal strength will be of the depth to which the former flood stirred the soil. The particles deposited by the first flood will be stirred up by the second, and carried (according to their weight, and the duration of the flood) so many yards or miles down the stream, and when the second flood subsides these particles will be deposited at the points to which they have been carried, and the places they occupied at the cessation of the first flood, will be filled by other particles from above.

46. II. The declivity may be such that the water shall only acquire velocity enough to scour out the soil in its deepest parts. The deep parts will therefore be cut away and a well-defined channel formed, but in this channel the water will have velocity enough to scour (though it will not generally become so turbid as to impair its fluidity) and will cut away the sides and bottom of the channel, and acting unequally on the former, will create bends which will lengthen the course and so reduce the declivity of the channel, till the velocity ceases to be sufficient to cause a scour and the stream acquires its *regimen*

47. The scour will have acted both on the bottom and sides, and, when it ceases, the bottom will generally be less easy of corosion than the sides, because of the lighter particles having been carried away, and the remaining soil consisting therefore of heavier particles retained in their place by their full force of gravity, while the sides, from which the lighter particles have been carried away, and the heavier fallen to the bottom, will consist of the usual size of particles set at a slope, and so not retained in their places by the full force of gravity. But the velocity on each part of the channel bed being greater where the depth is greater, the sides will be less acted on than the bottom, and a permanent shape of channel will be obtained as soon as the scour on each part has become no greater than each can resist without change. It follows that there is a regimen of Section of channel for every volume of water discharged in a given time with a given declivity of bed over each particular kind of soil, which regimen includes a particular relation of breadth to depth in the form of stability of channel.

D'Aubuisson Tte d'Hydraulique, p 161, para. 136, and p 163, para. 138

48. The regimen of width and depth of a river is subject to great variation in different parts of its course, from the nature of the soil it passes over. When it has acquired a regimen after scouring the finer particles out of a diluvial soil full of pebbles or coarse particles (which

latter will remain at the bottom and make it more difficult to scour than the sides,) the regimen will be of great width in proportion to the depth. On the contrary in passing through an alluvial soil having not only an uniform composition of fine particles, but a degree of plasticity, so that a considerable scour is necessary to detach particles from the bed, and but little to remove them when detached, the scour will take place to a greater degree at the bottom, and the channel will be comparatively deep and narrow.*

49. In subsiding from a state of flood, a river often passes from the first to the second "case" of action on the soil of its bed. The matter which was stirred up all over the bed in the times of most violent action, is deposited when the river falls, and through this deposit the reduce flood-stream cuts a defined channel and makes its pools and bends as above described.

50. A river passes in another sense from the first to the second case of action when it changes its declivity or the nature of its bed in proceeding down its course. The current is then not capable of carrying on all the matter moved forward by the stream above the place of change, and yet has some scouring action on its bed. The bed therefore rises and the winding of the stream is accelerated by deposits taking place on the concave sides of its bends, while a scour is going on on the convex sides.

51. This may also happen when the degree of scour in a stream in its upper parts not so great as to assume the character of the first case reduces slower down without altogether ceasing to act on the bed This was the case with the Eastern Jumna Canal above alluded to, with respect to which Lieutenant Morton states, that the deposit was so rapid that the

Printed Memorandum, page 9

"greatest exertions on the part of the Superintendent and his Overseers in raising the "banks were scarcely adequate to keep pace with the rising bed."

52. III. The declivity may be so small that the water shall have no power to scour the soil. The channel will consequently remain in the form given to it by the lowest part of the country and will be wide or deep according to the nature of the ground over which the water flows.

53. This case corresponds to that of a river after it has acquired its regimen, and when a river has not acquired stability of bed for its highest

* The following is from a note on Sherwill's Geological Map, describing a bed of clay North of Maldah "The bed of the Mohanuddy where it passes through the clay deposit, is narrow and deep, not more than 50 yards broad. Upon leaving the clay, the bed expands to 400 yards

floods or for floods at all, this case may correspond with its state when low. There is then often no sensible action on the bed.

54. If a portion of river channel in the state Case III. receive turbid water arising from a high velocity above, a deposit will occur in consequence of the current being too feeble to carry forward the matter brought down. The current may be too feeble even to modify the process of deposit, which in such a case will take place pretty uniformly over the bed, but most where there is most water. The bed will consequently become shallow and the water will spread out This is an instance of a wide and shallow bed produced by a different cause to Case I. In the first case the peculiarity arises from mobility of bed; in the last from want of power to carry off deposit. If a river be too wide and shallow from the first cause, to increase the scour would increase the evil; if the excessive width be owing to the last cause, it would afford a remedy.

55. Between the two extremes of violent scour as in Case I, and entire want of scour as in Case III, there must be many gradations of excessive and deficient action which may co-exist with wide and shallow beds; for each case a different course of procedure may be found the best to effect an improvement in the river. The following observations by D'Aubuisson on this subject appear useful. (Traité page 212.)

"The effects of the action of water are entirely different upon beds "of different natures; and works which produce a very marked effect "in one river or portion of river, may have none upon another. For "example, in the plains of Gascogny, where the rivers run with a small "declivity, over a very fine and moveable sand, M. Laval, by the aid of "simple spurs of hurdle-work, between which he lays down pines and "other trees with their branches attached, has cut away and deepened at "will the beds of these rivers; while on the Loire works of great solidity, "as masonry-dikes, transverse and submersible, (that is little raised "above the mean water level,) fixed to one bank and advanced to a "proper distance into the stream, have not been found to produce on the "opposite bank any sufficient increase of depth for the purposes of naviga- "tion: the *deblai* which they occasion at one point being often followed "by a *remblai* lower down the stream. As I have been led to speak of "works intended to produce increased depth in rivers, I may remark "that there is no certainty of effecting it but in restricting the current "between two longitudinal embankments, either submersible or insubmer- "sible, continuous, or formed of a succession of small lines leaving between

" them intervals by which the water may pass in floods, in order to fill " up with silt the space between the dikes and the old bank of the " river."

56 But to the improvement of river beds, for the purpose of navigation or to increase their discharging power, by the construction of embankments, there must be a limit. It has been seen that for each volume of water discharged with each degree of declivity over each kind of soil, there exists a particular ratio of depth to width of channel which cannot be exceeded without infringing the stability of the river's bed, and it follows that an increase of depth and decrease of width beyond this proportion will cause the water to act more on the sides than on the bottom. Consequently embankments made of the same substance as the bed of the river will not stand, if placed so close together as to cause the proportion of depth to width of channel to exceed the ratio of stability

57. From this it further appears that for each volume of discharge to be carried at each rate of declivity over each kind of soil, the velocity of the stream cannot be increased by means of embankments of the same soil, beyond a certain limit. Hence if the river above be fully charged with earthy matter from a greater velocity, a deposit must take place within the embanked channel, and the embanking will fail to prevent a rise of the river's bed. In such a case embankments can only be effective when made of a substance on which the scour will not act, and when founded so deep below the bed of the river as not to be liable to be undermined

58. The above appears all that it is necessary to state on the subject of width and depth of rivers. The following is concerning the scour and changes of declivity, and their effects on the successive portions of the channel.

59. A stream *uniformly* in the state described as Case I, must always have its water highly charged with solid matter, one uniformly in Case II, must have its water more or less charged, a third uniformly in Case III, will carry little or no solid matter.

60. These states will be assumed with different declivities for different kinds of soil. For instance a river may uniformly continue in the state Case III, when its course begins with excessive declivity over hard rock and then passes over boulders or shingle with reduced but still great declivity, after that over gravel with less declivity, then over sand with a slight fall, and finally over a light alluvial soil at a very small slope. This is the case of the regimen to which all rivers tend. It is frequently seen while a river retains only its ordinary discharge of water which

then is nearly clear throughout its course, but in floods the adjustment of the volume of discharge to the bed no longer holds, and the bed is scoured and the water becomes turbid.

61 In floods moreover, and in some cases when not in flood, rivers change their states in different parts of their course. The causes of such changes may be three.

I. Change of volume of discharge, owing to the state of the weather or otherwise.

II. Change in the nature of the soil.

III. Change in the rate of declivity.

62. Change in volume of discharge has the effect of increasing the velocity with the increasing discharge, and reducing it again as the discharge reduces. The rising flood therefore scours and the subsiding flood deposits If this action be unaccompanied by other changes in the river, it produces no progressive effect. It occasions the bed of the river always to be covered with a certain quantity of deposit which is carried away by every flood in rising, and replaced by a similar quantity brought down from above when the flood subsides.

63. Change of soil, unaccompanied by change of declivity, produces, as has been already shown, variations in their width and depth of channel. It also produces gradually changes in declivity, owing to light soils being scoured out and heavy firm soils resisting the scour, as will be more fully stated below.

64. Change of declivity in different parts of a river's course may, as has already appeared, exist with a stable bed when the declivity is adapted to the soil, when it is not so changes occur of which the most important to the question in hand are as follows —

65. When a stream descends from high land upon a sandy country having a considerable declivity, it assumes the wide bed, and its waters are not only charged with suspended matter but push more or less of the soil in a semi-fluid state along the bottom, as shown in describing the kind of action referred to in Case I. The slope of the country through which the river flows generally diminishes as it recedes from the hills The consequence is a reduction of velocity, (for it has been shown that a sandy bed will not allow of increase of depth) and a deposit of matter before moved along or held in suspension by the current. It will be useful to trace this process from the commencement in the case of a river flowing into the sea.

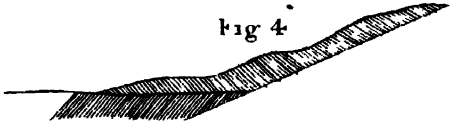
66 Supposing the country in the first place to have a uniform slope from the hills to the sea, and the soil to be uniform, the stream will carry down the whole of the matter it holds in suspension or keeps in motion, and will deposit it in the sea round its mouth, till at length the deposit rises to the level of the high water, and forms new land as shown by the shaded part *a b* in the diagram, Fig. 1; from *a* to *b* therefore there will be formed a new portion of river channel with but little slope There will consequently be a check in the current at *a*, and a further deposit will form there as shown at *c d* Fig. 2. Here it appears that between *c* and *a* the slope of the channel has been reduced, while between *b* and *d* it has been increased by this new deposit. While therefore this action occasions a further deposit about *e*, a scour will be caused about *d*, and the next phase the Section will exhibit will be such as Fig 3. The scour at *d* will form a new deposit about *b*, which will be continued upwards as before, so that the longitudinal Section of the river bed will take the form of a succession of waves, each of which will have a slow motion up stream (Fig. 4). On

Fig 1

Fig 2

Fig 3

Fig 4



the whole the rate of declivity will gradually reduce in proceeding down stream, but subject to the variations caused by these waves in each particular portion.

67. The progression of these waves of the bed up the river depends upon their receiving a deposit from the matter set in motion by the water on their up-stream or more horizontal sides while they are scoured away on their down streams or steeper sides. It follows that as the upper portion of the stream approaches its regimen, having scoured out the greater portion of the moveable matter of its bed, the first wave of the bed will receive less matter from above than is cut away from below, and will gradually diminish in height as it proceeds up the river and finally disappear, having in its progress on the whole slightly raised the concave portion of the curve of the longitudinal Section of the river's bed So it will be with the other waves in succession, each proceeding less for up than its predecessor, and by the time the river has by this means acquired its regimen of declivity, the waves will be very small and will occur only near the sea

68. But while the river is far from having attained its regimen, so that a wave of the bed may chance to receive a much larger accession of matter by deposit from above than was cut away from below, the rise of the bed may be so great that the wave shall become more or less of a dam, and by nearly closing the channel, force the water over the sides upon the country. The water so driven out of the channel will carry a great portion of the suspended matter with it, and so retard the deposit on the up-stream side of the bed wave, and delay its progress If the nature of the surface of the country be favorable to such action, the water forced out of the old bed of the river may cut a new channel for itself, in which case the old one will perhaps silt up, or it may raise the bank of the river gradually by depositing the suspended matter on the country right and left, till a sufficient height is gained to enable the stream to top the wave (which meanwhile will have been reduced by the scour from below) and the river will then resume its bed and the wave its progress up the stream. A river thus nearly dammed up by the progress of such bed-waves, may form for itself two or three or more new channels. In each of these similar bed-waves will occur, and these in their progress may close the channels again and force the water to find others. This process is most frequently observed at all the mouths of large rivers, such as the Ganges, &c.

69. Adverting to what has been already stated of the effect which the channel being cut through a homogenous alluvial soil will have

upon the width and depth of the bed, it will be found that the channels on the down-stream sides of these waves of rise in the bed will often be narrower and deeper than the channel above the wave.

70. It also appears that Sections across river-beds taken with the view of ascertaining the fact of a rise in the bed, may give very conflicting results if taken without reference to the state of the wave of rise. A Section taken near the crest or valley of a wave compared with one taken some years after at the same place, may show neither rise nor fall. Another taken on the down-stream side of a wave may, on the same comparison, show a slight depression from the scour in progress there. A third taken on the up-stream side may show more or less of rise.

71. The foregoing investigation appears sufficient to explain all the cases of rivers having a scour above, simply reducing in declivity as they flow towards the sea. But a river may increase in declivity or the scour may increase from other causes in a portion of it course, for instance in a river running over a hilly and high country Heavy falls of rain will cause all the tributary streamlets and even the hill sides to assume the state of scour described as Cases I and II, and the tributaries will carry consequently solid matter into the main stream, often increasing the action on their beds in proceeding down if they flow over light soil at a considerable declivity to meet the main river, on joining which, owing to the increased volume and mean depth, or perhaps also to the increased declivity of a rapid descent into the plains, none of the solid matter will be deposited, at least till the flood begins to subside It may be that no more will be taken up (except the deposit of former floods) in the part of the channel where the descent from the hills takes place, which having been so frequently scoured, will probably be left nearly clear of moveable particles; but the matter brought down from the hills will be great and will be carried forward until it comes to the point where the excessive declivity of the descent from the hills meets the more gradual slope of the plains. Here a deposit must take place either of shingle gravel or sand, or of all in succession, according to the geological formation of the hill country.

72. If the reduction of declivity from the hills to the plains be abrupt, and the nature of the country such that the matter carried along by the water of the river shall be chiefly sand, there will be a heavy deposit of sand at the debouchure of the river from the hills, and this deposit will form a sandy tract, having a considerable slope owing to its constantly receiving accessions from above while it is subjected to more or less of

scour from below, and must give rise to the state of channel in this part of the river described as Case I, the great width and small depth being further increased by the constant deposits from above.

73. The river course below this must be subject to the waves of rise in the bed just described and all the constant changes they produce, and these peculiarities will be further developed if the hills be steep and the country liable to heavy falls of rain. The waves of rise in the bed will not, in such circumstances, reduce as they approach the hills in their upward course, but on the contrary will often increase, and if the features of the country do not restrict the action of the river it will, by constant changes of its course, form a wide tract of sandy country round its debouchure from the hills.

74. To get rid of the deposit from the water of a river in such a state, it appears, from what has been already stated, that embankments, or increase of scour by increase of depth, will generally be inapplicable. The only other variable elements are those already enumerated.

1 The volume of discharge
2 The soil of the bed.
3 The declivity.

75 The only artificial ways of decreasing the scour by operating on the volume of discharge are, (1) diverting part of the water to other channels, and (2) holding back portion of the flood water in reservoirs, and letting it out when the river is low

76 The soil of the bed of a river can only be changed for short lengths, so that this element cannot be varied except in combination with the declivity, as will be stated presently

77 The total fall from the source of a river to the sea being invariable, the rate of declivity can only be reduced *generally* by increasing the length of a river's course by causing it to wind, but this is quite out of our power for any large stream. Partial reductions of declivity may be made by increasing it in one place and reducing it in another, and an artificial bed being made where the declivity is increased, the effect will be to reduce the scour upon the natural bed where it is decreased. This is sometimes done on small rivers and frequently on canals of irrigation, by the formation of artificial rapids, or weirs, or falls, between which the bed of the stream silts up to, or is retained at, a moderate declivity.

78 Except under peculiarly favorable circumstances none of these methods are likely to be practicable on a large river.

VI. On the state of the Damoodah Channel as regards declivity and deposits of sand, &c.

79. The Damoodah has a course of about 300 miles long. It receives the drainage of about 7,000 square miles, little or none of which falls into the river during the last 100 miles of its course, in which it is embanked, and has a flood level generally considerably above the country right and left.

80. The source of the Damoodah is about 60 miles West of Ramgurh. The river's course runs nearly due East through the great gneiss plateau of Sherwill's Map (but passing the Angwalee and probably other coal beds and sandy tracts) till just before its junction with the Barakur, about 150 miles from its source, and 75 miles West of Burdwan. The Barakur rises a few miles North of Hazareebaugh, crosses the Grand Trunk Road near Burhee, and again 100 miles nearer Calcutta at Taldanga, shortly after which it joins the Damoodah, having run a course of about 130 miles through a country of much the same geological formation as the Damoodah.

See Tassin's Map of Bengal, Captain Sherwill's Geological Map
Mr William's Map of the Damoodah coal fields

81. The two rivers, enter the Burdwan coal fields just above their junction, and carry with them the drainage of about 6,300 square miles of country After the junction of the Barakur the Damoodah receives several small tributaries, the last of which is the Buddye* which joins about 15 miles West of Burdwan

82. The rate of declivity of the Damoodah before its junction with the Barakur, can only be stated very roughly. The Section in Sherwill's Geological Map, gives the elevation of the Angwalee coal field about 850 feet above the level of the sea, but no authority is quoted, and possibly the elevation is merely a probable one. The Damoodah passes this coal field about 48 miles above its junction with the Barakur Professor Oldham gives the elevation of Taldanga (on the Barakur near the junction) at 401 feet The difference of level thus roughly determined, gives the fall of the river about nine feet per mile

Selections, Bengal Records, Vol VIII page 33

83. The levels of the Barakur can be stated in a more satisfactory manner. The upper crossing of the Grand Trunk Road appears from Dr. Hooker's journal to be not less than 1,300 feet above the sea, or 900 feet

Asiatic Journal, October 1848, Vol XVII, page 374

* The Buddye is a branch of the Damoodah, but receives the drainage of a portion of country before it rejoins the main river.

above the crossing at Taldanga The course of the river between the two places is about 110 miles, making the fall about eight feet per mile But lower down the river passes between Palmow and Palgunj, the elevations of which places are given by Professor Oldham at 744 and 833 feet respectively. Taking the river bank at 720 and the distance to Taldanga at 60 miles, the fall is $5\frac{1}{3}$ feet per mile for this portion of the stream

84. After the junction of the Barakur, the Damoodah runs about 37 miles through the coal measures, having at the junction, as already stated, an elevation of about 380 feet above the sea Twenty-four miles below the junction the railway levels make the elevation above the sea (at Bucktumnuggur) about 260 feet, which gives a fall of five feet per mile From Bucktumnuggur to the termination of the coal measures at Khyrasole, the fall appears to be about 29 feet in 13 miles, or $2\frac{1}{4}$ feet per mile, and near where the fall diminishes the width of the river suddenly increases from about 2,000 feet to one mile

85 In leaving the coal measures to enter the alluvial plains, the river again passes over a portion of the gneiss formation and appears to have a more rapid fall, being by the railway levels (of the country) 60 feet in about 16 miles, to Coolcool, 22 miles West of Burdwan In the next 16 miles of the country over which the railway passes there is a fall of about 52 feet to the Gowia Nuddee, which if it represent the declivity of the river fairly, will make the fall about three feet per mile, and this carries the stream 10 miles within the limits of the present survey, from which 72 miles of the river's course have already been described—28 miles more, subject to tidal influence, terminates the Damoodah in its junction with the Hooghly

86 Passing through the sandy formation of the coal measures, with the high rates of declivity above shown, and in a district liable to heavy falls of rain with long intervening periods of dry weather, the Damoodah, as might be expected, is subject to violent floods and brings down an enormous quantity of sand upon the plains

87. It appears to be a prevailing opinion that this quantity of sand is on the increase, and that at least as much comes down as the river can carry off from its debouchure from the hilly country upon the plains, but we have no accurate information to show that an accumulation is going on there

88. To facilitate the further study of the state of the Damoodah, a Section down the stream has been drawn, on which the general fall of the bed has been made clear by the use of a vertical scale 750 times as

large as the horizontal scale, and on which the deviations from regularity in the gradual reduction of the declivity have been further magnified in the proportion of 8 to 5.

89. From this Section it appears that two waves of rise of the river bed are in progress up that portion of the Damoodah which has been surveyed. The first has its crest about Futhapore, seven miles East of Burdwan; the second at Serampore where the Bancoorah road crosses the river. The up-stream side of the first extends to just beyond Joojooty, and comparing its position with the flood discharge of the river (*vide* Parts I and II of this note) along its course, it appears that the progress of this wave is the cause of the reduction in the channel of the Damoodah, and has forced three-fourths of its flood waters over the country between Joojooty and Futhapore. The progress of this wave appears to explain the fact, which the reports of the Officers of the survey show, that the country about and below Burdwan was once in a more prosperous state than it now is

90 The comparison of the Sections recently taken at Burdwan with that of 1837 appears to show that the progress of this wave is now almost suspended, probably by the quantity of earthy matter carried out of the river bed in heavy floods and deposited over the country *

91. Colonel Goodwyn's Sections, Nos V. and VII, will be found on the down-stream side of this wave, (the latter is now approached by the up-stream side of the next,) and the theory shows why the river there is deep and narrow, and this is confirmed by the transverse Sections of the country, (Nos VI and VII.,) which show that the scouring in progress is in soil formerly deposited by the river

VII On the possibility of improving the Damoodah Channel by placing the Bunds closer together in its upper parts.

92 On this subject it is first to be remarked that the Damoodah where it is broadest (above Joojooty) is in the state above described as Case I, or nearly so The channel has a great declivity and passes over a light sandy soil and is liable to a great influx of sandy deposit, and a wide bed has been shown to be the natural consequence of these circumstances The bed therefore cannot be made narrow by closing it in with embankments constructed of the soil through which it flows. Above

* A similar cause appears to have prevented the progress of the rise of the bed of the Cauvery, *vide* annexed extract from the Madras Engineer's papers

Joojooty, therefore, the proposal could only be carried out by constructing bunds of a much firmer soil brought from a distance, or by facing the banks with fascines, or stone, or some other substance that is capable of resisting the current. It would be necessary also to protect the embankments from being undermined by the stream Any such expensive work as this would, it appears, be inexpedient in this case

93. From Joojooty to Futhapore the river has a reduced slope, this part of its course being on the up-stream side of a wave of rise in the bed Here the stream might possibly be confined within embankments but the inevitable consequence would be a rapid rise of the bed The case would be precisely similar to that of the Eastern Jumna Canal. The deposit lower down from the excessive slope of that part of the Canal which passed over the sandy soil did not cease till the slope had been reduced to 1·38 feet per mile, with a discharge of about 6 or 800 cubic feet per second. Above Joojooty the Damoodah has a slope of 2 7 feet per mile (perhaps more higher up than the Maps show), with a discharge in floods of 600,000 cubic feet per second Between Joojooty and Futhapore the slope is on the average 1 6 feet per mile. It is evident that a deposit must occur from the reduction of declivity, for although the velocity might be maintained by increasing the mean depth from 10 to 17 feet,* this would not prevent the mass of semi-fluid matter carried along by the current over the excessive slope, stopping where that slope diminished, and blocking up the channel It is also probable that the increased velocity would prove to be more than the bunds would stand

94 Below Futhapore there is an increase of declivity arising from that portion of the river being on the down-stream side of the bed-wave, on the up-stream side of which the water has deposited its excess of solid matter The Sections show that a scour has taken place here, assisted no doubt by the maintenance of the bunds. It appears that the river has changed as follows —

	Mean depth	Area of Section	Fall per mile	Discharge
1837	14 0	14,315	2 2	95,911
1852	16 9	16,439		126,578

95 This gives an increase of about 32 per cent in fifteen years in the discharge, the extreme depth and flood rise remaining unchanged This improvement might no doubt be continued up to a certain limit, but the

* By raising the bunds, at first

foregoing theory shows that the scour at Culna will be followed by a rise as the next wave of the bed advances from below by virtue of the increase it receives from this same scour, so that the improvement could not be permanent. Moreover, if it were permanent, the process would afford no prospect of immediate relief from the inundations The scour that has taken place has increased the capacity of the channel 32 per cent. in fifteen years The capacity requires yet to be increased by 340 per cent of its present discharging power to carry off the full flow of flood waters, which increase, at the same rate of percentage, it would take 150 years to effect, and there appears to be no prospect of hastening the process in any sufficient degree.

96. It is evident that the Superintending Engineer South-eastern Provinces in making the suggestion to improve the Damoodah by increasing the scour, was not aware that the deficiency of scour he seems to allude to from Joojooty downwards is the effect of an excessive scour from the upper part of the river, nor had he become aware of the remarkable fact of the great deficiency of discharging capacity which the calculations from the levels since received show to exist in the river where his Sections V and VII were taken, for at paragraph 10, part of his letter he states—"in these narrow channels the embankments intact "on both sides have passed the flood waters." And again, para 19th, "there is no fear of any rise of flood above that shown in Nos V. and "VII, which have received and passed free the entire volume or that "alluded to in para. 10 of this part" (*i e* the 643,337 cubic feet per second)

VIII On the Project for increasing the Water-way of the Damoodah by retiring the Bunds on one side.

97 In Major Baker's Memorandum printed in the XIIIth No of the Selections from the Records of the Bengal Government, at paragraph 12, page 87, it is stated—"If according to the third project it be deter- "mined to retain the embankments, I have no doubt that they may "be re-constructed sufficiently far apart and with sufficient height and "Section, to contain and confine such floods as have hitherto been re- "corded, but the ultimate and unavoidable effect of such a measure "would be to raise the river bed, to necessitate a constant and propor- "tionate increase to the height and Section of the embankments, &c"

98. It is necessary, therefore, to examine into the possibility of increasing at a reasonable cost the flood discharge of the river in the way of widening its bed by retiring the embankments.

99. From the nature of the data, the examination must be confined to the cost of increasing the width by retiring the right bank embankments, but there appears to be no reason to suppose this a less favorable case than that of retiring the embankments on the left bank.

100 At Joojooty the river wants 100,000 cubic feet per second of the full flood discharge An addition to the channel made on the right bank to carry off this much water would have a mean depth of about 10 feet (*vide* Section of country) and the fall of the stream being two feet in the mile, the addition would require a width of

$$W = \frac{Q}{\frac{9}{10} d \sqrt{2 f d}} = \frac{100{,}000}{\frac{9}{10} \times 10 \times \sqrt{2 \times 2 \times 10}} = \frac{100{,}000}{18 \times 3\,16} = 1758$$

feet, the distance to which the bund must be retired

101. Proceeding in the same manner with the other Sections of the country drawn from the survey, the following table has been drawn up

No of the Section	Discharge of River at flood less than 600,000 cubic feet per second, by about cubic feet	Fall of River per mile, feet	Apparent mean depth of additional channel, feet	Consequent distance to which bund must be retired, feet	Depth of water which the bund must sustain at flood, feet	
III	100,000	2	10	1,758	10 3	
IV	350,000	1 6	9	8,216	8 1	
V	400,000	1 7	14 5	4,379	14 5	
VI	460,000	2 2	11 7	6,638	15 1	
VII	485,000	1 8	17 7	3,805	18 2	
VIII	500,000	1 1	15 0	6,496	17 3	
IX	500,000	1 2	14 0	6,841	16 7	
X	500,000	1 5	9 0	11,893	13 6	
XI	500,000	1 0	10 0	12,428	12 0	
XII	510,000	1 0	9 0	17,455	11 7	
XIII	525,000	0 7	8 0	21,970	8 0	

102. The content of the addition to channel considered as a bason to hold floods is

Section	Width	Mean depth (by inspection)	Areas of Sections		Length in miles	Products
			Of each	Means		
III	1,758	10	17,580			
				45,762	6 5	297,453
IV	8,216	9	73,944			
				68,719	7 0	481,033
V	4,379	14 5	63,495			
				70,579	8 0	564,632
VI	6,638	11 7	77,664			
				72,506	7 5	543,795
VII	3,805	17 7	67,348			
				82,394	6 0	494,364
VIII	6,496	15 0	97,440			
				96,607	6 5	627,945
IX	6,841	14 0	95,774			
				101,405	5 5	557,727
X	11,893	9 0	107,037			
				115,658	5 0	578 290
XI	12,428	10 0	124,280			
				135,687	4 5	610,591
XII	17,455	9 0	157,095			
				166,427	5 5	915,348
XIII.	21,970	8 0	175,760			
				Total,		5,671,168

5,671,168 × 5,280 = 29,943,767,040 cubic feet, which is equal to nearly fourteen hours of the flood discharge of 600,000 cubic feet per second The present channel has already been computed to be equal to eight hours' flood discharge The two together, therefore, are equal to contain twenty-two hours' flood discharge, that is to say, in the seventy-two miles of the river's course embraced in the survey

103. The flood of 1840 lasted four days before it began to subside For a bason therefore it would be necessary to have room for at least four days' flood, reckoning at full 600,000 cubic feet per second The capacity of the river channel with the additions is consequently quite inadequate to act as a bason, and must be kept in full efficiency as a channel

104. It is therefore very desirable to know the effect of a strong South wind upon the current of the river in so wide and shallow a channel as would exist in the lower parts of the Damoodah's course if this project were carried out

105. The only case at all in point found on record after a search through such works as are procurable in Calcutta, is that given at page

41 of Part II, Vol. III of Burnel's Treatise on Hydraulic Engineering, Weale's series. A pond, nine miles broad and of a depth of three feet at each side, (mean depth not given,) was emptied at one side and had its depth doubled at the other by a violent wind This wind therefore produced a slope of $\frac{2}{3}$ of a foot per mile.

106 No satisfactory application of this instance can be made for want of a recognised rule on the subject, but as the fall of the river for eight or nine miles above Omptah is scarcely more than two-thirds of a foot per mile, it appears necessary to make some further allowance for the effects of wind there than is afforded by the three feet above flood level allowed in the bunds of the upper parts of the river In the following calculations five feet have been allowed at Sections XII. and XIII and four feet at Section XI

107. Referring now to the table in which the position of the retired bunds are given, and to the sketches of them in red ink on the sheets of Sections of the country, it will be seen that they will not have merely to stand the effects of the scour of the comparatively slack water which in floods rises over the river's banks, but will themselves form the bank, and have to resist in many parts the greatest force of the stream In calculating the quantity of earth-work likely to be required in carrying out this project, therefore, the following scale of Sections have been taken·

Land slope 3 base to 1 height,
Width of crest $\frac{1}{2}$ height, ...
River slope 6 base to 1 height,

} Whence the area is $5h^2$, h being the height.

No of the Section	Depth of water to stand against, feet	Height of bund, feet	Area of Section of bund, feet	No of cubic feet in a mile	Means of foregoing	Length in miles	Total cubic feet.
III	10 3	13 3	884 4	4,669,632			
					3,961,056	6 5	25,746,864
IV	8 1	11 1	616 0	3,252,480			
					5,618,608	7 0	39,680,256
V	14 5	17 5	1531 2	8,084,736			
					8,366,504	8 0	66,933,504
VI	15 1	18 1	1638 0	8,648,640			
					10,256,928	7 5	76,926,960
VII	18 2	21 2	2247 2	11,865,216			
					11,372,064	6 0	68,232,384
VIII	17 3	20 3	2060 4	10,878,912			
					10,562,112	6 5	68,653,728
IX	16 7	19 7	1940 4	10,245,312			
					8,759,998	5 5	48,179,989
X	13 6	16 6	1377 8	7,274,484			
					7,016,542	5 0	35,082,710
XI	12 0	16 0	1280 0	6,758,100			
					7,060,416	4 5	31,771,872
XII	11 7	16 7	1394 4	7,362,432			
					5,912,016	5 5	32,516,880
XIII	8 0	13 0	845 0	4,461,600			
					Total cubic feet		493,726,147

Below Section XIII the river channel continues confined for about 20 miles and would probably require retired bunds say of 12 feet high This will add 720 × 5,280 × 20 = 76,032,000 cubic feet to the quantity of earth-work, making a grand total of 569,757,147 cubic feet

108 This work should include the removal of the old bunds on the right bank of all mounds or obstructions in the new channel as well as the construction of sluices. The cost altogether cannot be set down under 3 rupees per 1,000 cubic feet

or rupees	1,709,271
Add 12 per Cent. for loss of substance in first season,	2,05,112
Total capital to be laid out, ...	19,14,383
Annual cost, 4 per Cent interest, 6 per Cent Annual repairs, ...	1,91,438

109 The land required to be made over for the formation of the new channel will be—

Width			Length in Miles	Area in square Miles
Feet	or Miles	Means in Miles		
1 758	0 333	0 944	6 5	6 136
8·216	1 555	1 192	7 0	8 344
4 379	0 829	1 043	8 0	8 344
6 638	1 257	0 988	7 5	7 410
3 805	0 720	0 975	6 0	5 850
6 496	1 230	1 262	6 5	8 203
6 841	1 295	1 773	3 5	9 751
11 893	2 252	2 302	5 0	11 501
12 428	2 352	2 829	4 5	12 730
17 455	3 306	3 733	3 5	20 531
21 970	4 161			
10 560	2 000	2 000	20 0	40 000
		Total square miles,		138 800

The Bengal Beegah is 1600 square yards
1936 Beegahs go to one square mile

1388
8328
4164
12492
1388

2687168 Beegahs

110 The whole of this land would perhaps not be thrown out of cultivation, but a much larger portion would be so than now is by the floods which pass along country on the right bank of the river owing to the incompleteness of, or to breaches in, the bunds.

111 On the whole the additional security afforded to the country to the right of the new bund might cover the loss on the left of it, so far as land is concerned, but there would be a heavy loss in buildings, villages, &c.

112. Nothing need be set down to the cost of repairing breaches, or for remissions of revenue owing to the damage done by them, or for changes in the lines of embankments which might from time to time be necessary. Considering the extreme width of the channel in its lower parts, it may be supposed that if this project be practicable, an active and skilful Engineer would be able to more than repay the sums expended and lost from new lines of embankments and breaches, by gradually taking

back (up to a certain limit) portions of the land given over to the river, as the occurrence of partial increases of depth in the river bed (which would no doubt here and there take place during the progress of floods) might enable him to do so without reducing too far the capacity of the channel.

113 In considering the advantage of this project, it is to be observed that it will not secure the country against the danger of inundation from breaches, (for the greatest care could not avert such occasional sets of the current against the bunds as must breach them,) but would render the occurrence of such accidents much less frequent, and their consequences perhaps less disastrous, for the occurrence of breaches would no longer be a necessary consequence of high floods, nor would the discharge of a great body of water through them be necessary to the subsidence of the flood The carrying out of this project, however, would not lower the flood level of the river, and would only afford so much additional security to the land on the left bank as is the consequence of breaches being no longer a necessary effect of floods.

See Major Baker's Memorandum

114 A very strong objection to the project arises from the position of the new bunds before adverted to Owing to the fall of the ground in receding from the present channel of the river, the new bunds would in most places have to stand the scour of the deepest and swiftest parts of the stream (excepting that of the old bed) The effect of a stream of water from 15 to 18 feet deep, running with a velocity of from five to eight feet per second, would probably be greater than a mere earthen embankment could stand even with the liberal section allowed in the foregoing calculations, and it would most likely be necessary either after all to abandon the bunds, or to face them and secure their bases, at an enormous expense, by means of stone or some other substance, which appears almost impracticable from so considerable a length of line

115 With respect to the possible rate at which the channel might silt up, it may be remarked that the full flood discharge of one day is 600,000 × 60 × 60 × 24 = 51,840,000,000 cubic feet of water, containing according to Major Kennedy's estimate* $\frac{1}{861}$ of its bulk of solid

* This estimate does not appear to be taken from any trial on the Damoodah, it is probably Captain (now Lieutenant-Colonel) Forbes' determination for the Ganges, subsequently verified by the Reverend R Everest, *vide, Asiatic Journal*, Vol I, (1832) Mr Everest's experiments were made at Ghazeepore, where the Ganges has a fall of about one foot* per mile The estimate is therefore probably very far short of the actual quantity of solid matter carried by the Damoodah water, in high floods, above Burdwan

* Dr Hooker *Asiatic Journal*

matter, or about 60,000,000 cubic feet; enough to cover a square mile to the depth of about $2\frac{1}{10}$ feet If the whole flow of water during one rainy season be reckoned equal to eight days' full flood discharge, it will bring down enough solid matter to cover a square mile to the depth of about 17 feet Two-thirds of this might possibly be deposited* on the up-stream side of the great wave of rise in the river's bed between Joojooty and Futhapore, over about 24 miles of the river's course, where, when widened, it would on the average be $1\frac{3}{4}$ miles wide, that is over 42 square miles On this space the average rise would thus be $\frac{10}{42}$ or about $\frac{1}{4}$ of a foot per annum, and in the middle portion it might be as much as $\frac{1}{2}$ a foot, and, if the process continued at this rate, the channel would completely silt up to present flood level in 42 years

116 These objections and the heavy outlay required, together with the imperfect and unsatisfactory nature of the relief afforded to the country, appear to be conclusive against this project.

IX Impossibility of improving the state of things by cutting new Channels for the Damoodah

117 The next project for preserving the country from inundations which presents itself is that of making new channels of sufficient capacity to carry off the floods There is a considerable fall from the Damoodah near Joojooty to the Dalkissore, and a channel about $15\frac{1}{2}$ miles long would connect the rivers, and so the latter might be made to carry off the surplus water from the former in times of flood This cut, with the assistance of improvements in the Canna Nuddee and Damoodah Khal, might be made to carry off all the flood water which cannot be passed down by the Damoodah at Omptah At first sight the project appears very feasible

118 But on calculation it appears that the immense extent of water-way required for the new cut will make the expense of such a measure much too great Referring to the table in the first Section of this memorandum, it will be seen that the following arrangement for carrying off the floods is the most favorable that can be made, that is, it gives the least possible discharge to the new cut from about Joojooty In fact it requires the Damoodah to carry 200,000 cubic feet per

* It would cost Rupees 3,20,000 to remove it outside the bunds, if it could be done at 1,000 cubic feet per Rupee This charge might be annual

second as far as the Canna Nuddee, which it will not do without considerable excavation or raising of bunds

New cut, ...	400,000	cubic feet per second
Canna Nuddee,.....	100,000*	ditto.
Damoodah Khal, ...	25,000	ditto
Damoodah at Omptah, ...	75,000	ditto
Total, . .	600,000	

being the full flood discharge

119. Whatever be the eligibility in other respects of the line of the Joojooty Section for the new cut, it appears that no more economical line can be chosen Above it the ground rises too high, and below it the distance increases This line gives a fall for the new bed of two feet per mile, a mean depth of cutting of $22\frac{1}{2}$ feet to bring the bottom of the cut to an even fall between the bottoms of the two rivers, and a length of $15\frac{1}{2}$ miles. The extreme flood depth of the river at Joojooty is about 21 feet, and the new cut cannot have a mean flood depth greater than this without loss of fall and increase of cutting With the mean depth of 21 feet and fall of two feet per mile, Eytelwein's formula gives the flood width of channel thus—

$$\text{Discharge } 400{,}000 = W \times 21 \times \tfrac{9}{10}\sqrt{2 \times 2 \times 21} = 172\,9\ W$$

$$\therefore\ W = \frac{400{,}000}{172\,9} = 2292 \text{ feet}$$

To allow for the sloping off the sides, say 2,350 feet for the width of cutting, then the quantity of excavation will be

$2350 \times 22\frac{1}{2} \times 5280 \times 15\frac{1}{2} = 4{,}327{,}290{,}000$ cubic feet, which at [illegible] Rupees † per 1,000, would cost $259\frac{1}{2}$ lacs of Rupees

* The Canna Nuddee in its present state will not carry off $\frac{1}{10}$th of this, as far as can be judged from the Section given by Lieut Johnstone It appears to have a flood area of about 1 400 square feet, with a mean depth of ten feet, and fall of one foot per mile It is without bunds, by the application of which the discharging power might be increased The length of the channel is 50 miles

† To place the earth clear of the bank out of danger of falling in from the lateral action of the stream, and to avoid raising the earth unnecessarily, it must be carried on the average nearly half a mile with a rise of 30 feet This would probably cost six annas per 100 and four annas for excavation and loading, dressing, total ten annas per 100, or 100 annas per 1,000

120. With the addition of the improvements to the Canna Nuddee and Damoodah Khal, and the embankments which would be necessary on Dalkissore below the junction of the new cut, the cost of this scheme could not fall short of three (3) crores of Rupees.

121 And notwithstanding this large outlay no permanent relief would be afforded to the country. For, admitting that the narrow cut above calculated for would stand the floods, the fall of the Dalkissore which continues at about two feet per mile about as far as Jehanabad, reduces below that place to only one foot per mile This reduction of declivity would occasion a rapid deposit of the sand and silt brought down the new cut in large quantities, and the Dalkissore channel would soon become as inefficient as the Damoodah now is

X Proposal to remove the Bunds on the right Bank

122 The Sections drawn from the survey of the country show that the lowest land on the right bank of the Damoodah, to which the floods of the river can have access between it and the Dalkissore or Roopnarain, lies along the bank of the Damoodah as far as where the Damoodah Khal branches off opposite Rajabulhaut, (a village on the left bank of the Damoodah,) and that below this the country has no general feature but a slight fall towards the Roopnarain It seems therefore that in the event of the removal of the right bank bunds, the main body of the water which the river channel cannot contain will flow along the right bank of the Damoodah as far as opposite Rajabulhaut, and from that place will spread over the country, and most of it fall into the Roopnarain in that part of its course which is a few miles North and South of the latitude of Omptah, that is about opposite Gopeegunge

123. In the Report of Mr Denton, Executive Officer of the Culmeejole Division, dated 3rd July 1840, describing the great flood of that year, the above conclusion is confirmed by the following statement —

" The country between the Damoodah and Roopnarain being one sheet " of water, and the waters of the former river running over the bunds " of the latter into the river below and above Goopeegunge "

124 There will, it appears, be no difficulty in draining off the flood water, but most of it must be carried into the Roopnarain, and very little can be brought back into the Damoodah

125 In order to calculate the level to which the floods will rise upon the low ground between the two rivers, the areas of all the Sections

of the country perpendicular to the Damoodah's course have been calculated for various flood levels, assumed at intervals of one or two feet, from the river flood level downwards.

126 The water-way afforded by the low country in the first and second Sections has not been taken into account, the areas being so small that the water carried off would evidently not affect the flood level which would remain the same as in the river.

127. At Section III, (Joojooty,) the river has been assumed to carry off 400,000 cubic feet of water per second, and the low land 300,000, and as the river, bunded, is capable of carrying off nearly 500,000 cubic feet per second in that part, and as the full flood discharge is supposed to be only 600,000 cubic feet per second, these assumptions appear to allow of ample margin for errors.

128 At Section IV, (Burdwan,) the river is supposed to carry off 250,000 cubic feet per second and the low land 450,000

129. For Sections V to XI inclusive, the low land is assumed to carry off the full flood discharge, leaving what is carried off by the river as "margin".

130 From Section XI downwards, the flood water has an escape into the Roopnarain, and judging by the fall in the direction of the Damoodah stream and towards the Roopnarain, it appears that from Section XII not more than 450,000 cubic feet per second, and in Section XIII not more than 300,000 cubic feet per second will flow over the low ground, the remainder falling into the Roopnarain * The above numbers have accordingly been assumed for the discharge in determining the flood levels which have been calculated with a corresponding slope towards the Roopnarain. The information as to the floods on this part of the country is imperfect for want of levels on the right bank of the Roopnarain and lower down that river.

131 The fall of the flood stream per mile has, in the first instance, been assumed to be that of the lowest land shown in the Sections, that is, the difference of level between the lowest ground of the preceding and following Sections, divided by the number of miles between them.

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* These deductions I have since seen reason to think too great, and conceive the land flood should be calculated to carry off 500,000 cubic feet By drawing the flood line on the Sections horizontal from the Damoodah side, instead of on a slope, the error will be corrected, and it will be seen that it is not important

132. The following table shows the result·—

Section	Flood levels variously assumed	Width of Flood	Mean depth	Fall per mile	Velocity in feet per second	Areas of Section of flood	Discharge cubic feet per second	
I	209 3	16,000	9 4	0 2		150,270		
„	207 0	15,800	7 1	..		111,890		
„	205 0	15,600	5 3			81,670		
„	203 0	15,600	3 1	..		49,210		
„	201 0	11,100	2 1	.	.	23,750		
„	200 0	8,900	1 5		...	13,750		
II	200 0	6,500	3 0	2 0	3 1	19,500	59 670	
„	199 0	6,500	1 9		2 4	12,350	30,011	
„	198 0	4,000	1 5		2 2	6,100	13,176	
III	188 0	28,300	5 2	2 6	4 7	145,320	683,004	
„	187 0	25,800	4 6	..	4 4	117,860	519,763	
„	186 0	23,300	4 0	..	4 2	93,310	386,303	Flood 185 2 gives 300,000 cubic feet per second
„	185 0	20,800	3 4		3 8	71,260	269,363	
„	184 0	15,800	3 4	.	3 8	54,210	202,914	
„	183 0	15,800	2 4		3 2	38,510	121,307	
IV	175 5	30,600	5 1	2 1	4 2	156,873	649,442	450,000 cubic feet per second carried off by flood at 174 3
„	174 0	26,900	4 2	.	3 8	112,920	426,838	
„	173 0	24,400	3 6	..	3 5	47,270	30,635	

Section.	Flood levels variously assumed	Width of flood	Mean depth	Fall per mile	Velocity in feet per second	Areas of Section of flood	Discharge cubic feet per second	
IV	172 0	21,900	3 0	2 1	3 2	66,370	209,066	
,,	171·0	19,400	2 3	2 1	2 8	44,470	123,071	
V	166 5	39,500	13 7	2 7	7 7	361,040	2,803,108	
,,	163 0	39,500	10 2		6 7	270,970	1,815,499	
,,	161·0	37,000	8 2		6·0	217,790	136,740	
,,	159 0	31,500	6 2		5 3	164,610	872,433	600,000 cubic feet per second discharged at flood level of 157 6
,,	157 0	34,500	4 2		4 3	111,430	479,149	
,,	155 0	25,000	3 4		3 8	67,230	249,474	
,,	153 0	15,000	2 2		3 1	32,990	100,919	
VI	150 0	50,000	12 6	2 5	7·1	380,790	2,703,609	
,,	146 0	45,000	9 2		6 1	260,580	1,589,538	
,,	144 0	42,500	7 3		5 4	204,990	1,106,946	
,,	142 0	42,500	5 3		4 6	148,690	681,074	600 000 cubic feet per second at flood of 141 2
,,	140 0	30,000	4 7		4 4	103,010	453,241	
,,	138 0	27,500	2 7		3 3	59,711	197,046	
,,	136 0	15,300	1 8		2 7	23,770	64,179	
VII	133 8	22,000	9 5	2 1	5 7	159,410	903,855	
,,	132	19,500	8·7		5 4	129,520	699,408	600,000 cubic feet per second at 131 2
,,	130	19,500	6 7		4·8	99,970	476,857	
,,	128	17,000	5 4		4 3	71,050	306,936	
,,	126	17,000	3 4		3 4	45,000	153,900	
,,	124	9,500	3 5		3 4	25,660	87,757	
VIII	124 8	37,300	11·0	1 6	5 3	379,680	2,012,304	
,,	121 0	37,300	7 2		4 3	249,130	1,071,259	
,,	119 0	32,500	6 1		4 0	182,120	728,480	600,000 cubic feet per second at 118 2
,,	117 0	30,000	4 4	*	3 4	123,870	421,158	
,,	115 0	25,000	3 1		2 8	70,920	198,576	
,,	113 0	20,000	1 4		1 9	26,710	50,749	
IX	119 0	40,900	13 2	1 3	5 4	540,100	2,916,540	
,,	115 0	40,900	9 2		4 6	376,500	1,731,900	
,,	111 0	36,700	7 4		3 9	233,460	910,494	
,,	109 0	36,700	5 9		3 5	171,110	598,885	600,000 cubic feet per second at 109 nearly
,,	107 0	31,100	3 9		2 9	113,850	330,165	
,,	105 0	26,100	2 5		2 3	58,900	135,478	
,,	103 0	17,000	0·9		1 4	15,040	21,056	

The *widths* are the lengths of Sections The *areas* have been reduced to what they would be measured perpendicular to the river's course. The *Sines* or multipliers are

V —0 9348 VI —0 8660 VII 0 7660 VIII 0 9205

which must be applied to the *width* given to show the *width* of flood

Section	Flood levels variously assumed			Width.	Mean depth	Fall per mile	Velocity	Area	Discharge.	
	Damoodah side	Dalkissore side.	Middle of stream							
X			108	50,000	7 5	1 6	4 4	377,250	1,659,900	
,,			106	47,500	5 8		4·0	279,000	1,116,000	
,,			104·	40,000	4 7		3 5	188,000	658,000	600 000 cubic feet per second at 103 7
,,			102	3,250	3 4		3 0	110,750	332,250	
,,			100	20,000	2 9		2 7	58,000	156,600	
,,			98	10,000	2 6		2 6	26,000	67,600	
XI	104 0	100·1	102		10 8	1 5	5 1	867,510	4,424,301	
,,	98·	94 1	96		5 0		3 5	389,750	1,369,125	
,,	96	92·1	91		3 4		2 9	242,750	703,975	600 000 at 95 4 Damoodah 91 5 Dalkissore 93 4 Middle
,,	91·	90 1	92		2 5		2 5	124,750	311,875	
,,	92	88 1	90		1 6		2 0	41,750	83,500	
,,	90	86 1	88 0		1 6		2 0	12,500	25,000	
XII	97 4	92 2	94 8		8 7	0 6	2 9	454,700	1,318,630	
,,	95 0	89 8	92 4		6 3		2 5	329,900	824,750	
,,	93 0	87 8	90 4		4 3		2 0	228,900	451,800	450·000 at about Damoodah, 93 0 Dalkissore, 87 8 Mean, . 90·4
,,	91 0	85 8	87 8		3 1		1 7	128,400	218,280	
,,	89	83 8	85 6		1 9		1·4	53,900	75,460	
XIII	92 5	87	89 7		7 5	0 33	2	383,140	766,280	
,,	91 0	85 5	88 2		6 0		1 8	310,640	559,152	
,,	89·0	83 5	86 2		4 0		1 5	209,440	314,100	300 000 at Damoodah, 88 9 Dalkissore, 83 4 Mean, ... 86 3
,,	87 0	81 5	84		2 3		1 1	109,610	120,571	
,,	85	79 5	82·		1 3		0 84	36,360	30,542	

133. Comparison is made of the slope of the surface, as given by the flood levels required to carry off the water, with the slope of the lowest ground used in the preceding calculations in the following table :—

Section	Levels of		Difference of levels between preceding and following Sections		Distance between the Section preceding and following in miles	Fall per mile		
	Low ground	Floods	Low ground	Flood		Low ground	Floods.	
I	197 0	River, 209 3	1	9 2	5	0 2	1 8	
II	196 0	,, 200 1	22 2	22 7	11½	2 0	2 0	
III	174 8	,, 188 0 Land, 185 2 Mean, 186 6	31 0	26 2	12	2 6	2 2	
IV	165 0	River, 175 5 Land, 171 3 Mean, 174 9	25 5	29 1	12	2 1	2 4	Used, 2 5 fall
V	149 3	Land, 157 5	33 0	33 7	12	2 7	2 7	
VI	132 0	,, 141 2	30 2	26 3	11	2 7	2 4	Used, 2 5 fall
VII	119 1	,, 131 2	23 0	23 0	11	2 1	2 1	
VIII	109 0	,, 118 2	18 1	22 7	10	1 8	2 2	Used, 1 6 fall
IX	101 0	,, 109 0	14 9	14 5	9½	1 5	1 5	Used, 1 3 fall
X	94 1	,, 103 7	17 2	15 6	9¾	1 7	1 5	
XI	83 8	,, 93 4	13 7	13 3	9	1 5	1 5	
XII	80 4	,, 90 4	5 1	7 1	8¾	0 6	0 8	
XIII	78 7	,, 86 3	1 7	4 1	4¾	0 35	0 9	

134. The following Section's flood levels appears to require re-calculation with the slopes noted —

III	2·3	IX	1 5
IV	2 3	XII	0 8
VIII.	2 2	XIII	0 7

Section	Flood level			Mean depth	Fall per mile	Velocity	Area	Discharge	
	Damoodah side	Dalkissore side.	Mean						
III			187	4 6	2 3	1 1	117,860	483,226	
,,			186	4 0		3 9	93,310	363,909	300,000 cubic feet per second at 185 4
,,			185	3 4		3 6	71,260	256,536	
IV			175 5	5 1	2 3	4 4	156,870	690,225	
,,			174 0	4 2		4 0	112,920	451,680	450,000 cubic feet per second at about 174 0
VIII			119	6·1	2·2	4 6	182,120	837,752	600 000 cubic feet per second discharged at 117 4
,,			117	4 4		4 0	134,500	538,000	
IX			109	5 9	1 5	3 8	171,110	650,218	600 000 discharged at 108 6
,,			107	3 9		3 1	113,800	351,935	
XII	93 0	87 8	90 4	4 3	0 8	2 4	225,900	542,160	450 000 cubic feet at 92 4, 87 2, 89 5
,,	91 0	85 8	87 8	3 1		2 0	128,400	256,800	
XIII	89	83 5	86 2	4	0 7	2 1	209,440	139,827	87 9 300,000, at 82 4 84 9.
,,	87	81 5	84 0	2 3		1 6	109,610	175,376	

135. The flood levels now stand:—

Section	Flood level	Difference of level	Distance miles	Fall per mile		
				Found	Used	
II.	River, 200 1					
III.	Land, 185 4 River, 188 0 Mean, 186 7	25 4	11 5	2 1	2 3	
IV	Land, 174 0 River, 175 5 Mean, 174 7	29 2	12	2 4	2 3	
V	Land, 157 5	33 5	12	2 8	2 7	
VI	141 2	26 3	12	2 4	2 5	
VII.	131 2	23 8	11	2 2	2 1	These appear sufficiently near each other
VIII	117 4	22 6	10	2 3	2 2	
IX	108 6	14 7	19½	1 5	1 5	
X	103 7	15 2	9¾	1 5	1 6	
XI	93 4	14 2	9¾	1 5	1 5	
XII	89 5	8 5	8¾	1·0	0 8	Discrepancy on safe side
XIII	84 9	4 6	4¾	1 0	0 7	

The calculations now appear sufficiently correct.

136. The results as respect the flood level on the low land compared with that of the river, and the nature of the flood to which the country will be subjected, are as follows:—

Section	Land flood	River flood	Difference	Land flood				Width
				Greatest		Mean		
				Depth feet	Velocity feet per second	Depth	Velocity	Miles
I		209 3	0					
II		200 1	0					
III	185 4	188 1	2 6	10 6	7 3	3 7	3 7	4
IV	174 0	175 5	1 5	6 9	6 3	4 2	4 0	5
V	157 5	166 5	9 0	8 2	7 4	4 0	4 2	7
VI	141·2	150 8	9 6	9 2	7 3	4 3	4 1	6
VII	131 2	137 7	6 5	12 1	7 8	7 7	5 1	3½
VIII	117 4	128 7	11 3	8 4	6 8	4 7	4 1	5½
IX	108 4	119 0	10 6	7 4	5 3	5 4	3 6	6½
X	103 7 means	108 0	4 3	9 6	5 9	4 6	3 4	8
XI	93 4	104 0	10 6	7 8	5 3	3 1	2 8	13½
XII	89 5	97 4	7 9	9 3	4 7	4 0	2 3	11
XIII	84 9	92 5	7 6	6 2	3 9	3 2	1 9	9

137. The depth and velocity of the water in each portion of the flood and the extent of land flooded, are shown upon the accompanying copy of the survey.

138. The first point for consideration, with reference to the great difference of levels above shown, is the effect of the removal of the embankments of the right bank on the flood level of the river. To calculate this, the out-fall over the right bank for a given portion of he river may be taken as a stream, of a mean depth equal to the average height of the (reduced) flood level of the river above the bank, and of a declivity determined by the profile of the ground beyond the bank Then the discharge through the upper Section of the portion of the river under

consideration being known, the height of the water at the lower Section must be so determined that the discharge down the river there, together with the discharge over the right bank, will be equal to the discharge from above. In this way the calculation may be made for the successive portions of the stream, commencing from where the land flood ceases to be nearly on a level with the river flood. This is the case at the Burdwan Section, No. IV. The calculation will therefore commence with the interval between that and Selalpore (Colonel Goodwyn's Section No. III.) being the first detailed Section of the river below Futhapore (Section No. V.) The fall over the bank judging by the two nearest Sections of the country is about 2·7 feet in the mile at Selalpore. At Burdwan the fall is very small (1 5 feet being the whole difference of level between the river and land floods,) let the average therefore be supposed 1 3 feet all along from Burdwan to Selalpore. The height of the spill at Burdwan appears by Colonel Goodwyn's Section to be about four feet Let that at Selalpore be x, then the average spill, or mean depth of the water flowing over the bank, will be $\frac{x+4}{2}$. By Eytelwein's formula therefore the mean velocity of the flow over the bank will be

$$\tfrac{9}{10}\sqrt{2 \times 1\,3 \times \frac{x+4}{2}}$$

and the length of the portion of the river being 12 miles or 63,360 feet, the whole discharge over the bank will be

$$63{,}360 \times \frac{x+4}{2} \times \tfrac{9}{10}\sqrt{2\,6 \times \frac{x+4}{2}}$$

$$\text{or } 91{,}238 \left(\frac{x+4}{2}\right)^{\frac{5}{2}}$$

This mode of calculation though not strictly accurate is, as will presently appear, sufficiently so for the purpose.

139. On examining the Sections of the country Nos. V and VI, it appears that the removal of the bund on the right bank will leave an extreme depth of about 16 feet to the channel. With this as the extreme depth of water, Colonel Goodwyn's Section No III gives the area of 11,739 square feet, and a mean depth of 5 2. At full flood level the extreme depth is 23 5 feet, and the area 28,716, the mean depth being 9·5. Between these limits every foot of increase in extreme depth makes on the average a difference of 2,263 square feet of area, and 0·57 feet of mean depth. Wherefore at the height of x above the bank, the area of the Section of the stream will be 11,739 +

2263 x, and the mean depth $5{\cdot}2 + 0{\cdot}57\,x$. The fall being 2·1 feet per mile, the discharge down the river will be

$$Q = (11{,}739 + 2{,}263\,x)\ \tfrac{9}{10}\ \sqrt{4{\cdot}2 \times (5\,2 + 0\,57\,x)}$$

But the discharge at Burdwan being 253,082 cubic feet per second, the mode of calculation laid down above leads to the equation.

$$253{,}082 = Q + 91{,}238 \left(\frac{x+4}{2}\right)^{\frac{3}{2}}$$

Whence $\left(\frac{x+4}{2}\right)^{\frac{3}{2}} = \frac{253{,}082}{91{,}238} - \frac{Q}{91238}$

and $x = 2\left\{ 2{\cdot}77 - \frac{Q}{91{,}238} \right\}^{\frac{2}{3}} - 4$

so that whatever value be assigned to Q, x will be a *minus* quantity, that is to say, the river flood stream will not rise over its right bank at Selalpore. Under these circumstances the discharge down the river will not exceed $11{,}739 \times \frac{9}{10} \sqrt{4\,2 \times 5\,2} = 49{,}655$ cubic feet per second.

140. As this is 50 per cent less than the discharge which can be carried off by the river at Omptah, it appears that the removal of the bunds on the right bank as far down as Selalpore, only, will be all that is necessary in order to save the bunds on the left from danger of being topped by the floods and breached further down than a few miles East of Burdwan.

141 The above, though a very rough calculation, cannot, from the nature of the case, be liable to any very important error, because the declivity of the flood over the bank increases so greatly in proceeding from Burdwan to Futhapore, (Section V,) that any error in the assumed data which might affect the accuracy of the result for a space commencing at Burdwan, will entirely disappear if the calculation be made applicable to a space two or three miles lower down the river; so that it may safely be concluded that the bunds on the right bank need not be removed below a point opposite the head of the Canna Nuddee, provided that they be entirely removed in the upper portions of the river, and the country near them sufficiently cleared of obstructions.

141½. The capacity of the bason afforded by the low country, up to the flood levels ascertained by the calculations before given, will be as follows:—

Sections	Areas	Means of Areas	Miles	Products	
I	150,270				
		84,885	5 1	432,903	
II	19,500				
		49,790	6 5	403,635	
III	80,080				
		96,500	5 2	501,800	
IV	112,920				
		127,982	6 0	767,892	
V	143,045				
		128,708	5 0	643,540	
VI	114,371				
		108,648	5 8	630,158	
VII	102,925				
		129,427	4 0	517,708	
VIII	155,929				
		160,387	5 0	801,985	
IX	164,896				
		170,629	4 8	919,016	
X	176,412				
		192,381	5 0	961,905	
XI	207,350				
		199,750	3 8	758,950	
XII	192,150				
		171,297	5 0	856,485	
XIII	150,445				8,195,977
					5280
		Total,		8,195,977	655678160
					16391954
					40979885
				Total cubic feet, ...	43274758560

equal to 20 hours' discharge of the full flow stream.

142. The area that will be submerged may be roughly set down thus:

Section	Width Miles	Means of Width	Length Miles	Areas Square Miles	
I	1 75	1 57	5 1	8 45	
II	1 40	2 7	6 5	17 50	
III	4 0	4 5	5 2	23 40	
IV	5 0	6 0	6 0	36 00	
V	7 0				
	angle	7 0	5 0	35 00	
VI	5 0				
VII	4 0	4 5	5 8	26 10	
VIII	5 5	4 75	4 0	19 00	
IX	6 5	6 00	5 0	30 00	
X	8 0	7 25	4 8	34 80	
XI	13 5	10 75	5 0	53 75	
XII	11 0	12 25	3 8	46 55	
XIII	9 0	10 0	5 0	50 00	
		Total,		380 65	Square Miles
		or Beegahs, ...		736,938	

143. It has been proposed to construct a central bund near the southern and western limit of the flood stream, and it would no doubt be useful to protect the land within it from the effects of a rise of water, or from waves in case of a high wind accompanying the heavy flood. It would also afford the Revenue Officers a great advantage in defining, to the satisfaction of all parties, the limit to which the floods would be confined, and it would afford a margin for errors in the calculation of their rise If this bund were placed on the line at which the water would submerge the land to a depth of two feet, a small area of land would be saved from occasional inundation, and no useful water-way would be taken from the flood The proposed bund is sketched on the map, it would be about 69 miles long and of a Sectional area of $5(3+\frac{7}{2}\times 5) = 102\,5$ square feet, and would contain $102\,5 \times 5280 \times 69 = 37{,}342{,}800$ cubic feet of earth-work The cost of construction would be about 40,000 Rs. The abrupt turns may be cut off without much increasing the expense and with no loss of water-way

144 The construction of this bund will reduce the area of land to be given over to the floods to about 350 square miles or 677,600 beegahs

145 It was at first proposed* to protect the Mundulghaut Pergunnah by a cross bund running from Omptah to opposite Gopeegunge on the Roopnaram, but the present survey shows that such a measure would be impracticable, because, owing to the small capacity of the channels of the two rivers, there would not be left sufficient water-way to carry off the floods, and the bulk of water is too great to be dammed up† As the survey terminates at the line of the intended bund, the nature of the measures to be adopted to protect the Mundulghaut estate cannot be accurately stated, but from the accompanying sketch map, compiled from the Revenue Survey and other maps in the Office, and from the circumstances stated below, some rough approximation may be made to the nature and cost of the works required.

146. Further south than the line of the formerly proposed bund, below the Buxee Khal on the Roopnaram side and the Gaighattee Khal on the Damoodah side, and forming a curve convex to the north between them, is a strong embankment for the protection of lower Mundulghaut.

* Military Board's letter, No 2692, of 6th January 1852, para 20

† Four days' flood 600,000, $\times$ 60 $\times$ 60 $\times$ 24 $\times$ 4 = 207,360,000,000 cubic feet A square mile covered with water 20 feet deep will have $20 \times 5280^2 = 20 \times 28{,}000{,}000$ = 560,000,000 cubic feet of water on it, whence it appears that four days' flood discharge of the Damoodah would lay 370 square miles of country under water to a depth of 20 feet

This embankment approaches close to both rivers. It has been breached, or else has caused the floods to rise so high as to oblige the villagers to cut it, on several occasions, and the Midnapore and Ooloobarreah road, which should be protected by it, is frequently injured. It appears therefore that this bund does not allow sufficient water-way for the floods under the existing state of things, and it therefore will not answer at all for the protection of the lower Mundulghaut when the bunds on the right bank of the Damoodah are removed and the flood over the country increased by all the water which heretofore used to find its way through the breaches on the left.

147. The country in the latitude of Omptah having a slope towards the Roopnarain, and that river having a so much more capacious channel in its lower parts than the Damoodah, it appears necessary to provide for the passing off of the flood-water entirely on the Roopnarain side The Section taken by Lieutenant Jervis in 1850, shows that the Roopnarain at Coila Ghaut, where the Ooloobarreah and Midnapore road crosses, has a width of about 2,000 feet and a Section which affords a water-way of not more than 50,000 square feet for high floods This river therefore, allowing a fall of one foot per mile, cannot be reckoned upon to discharge more than $50{,}000 \times \frac{9}{10}\sqrt{2 \times 1 \times 25} = 320{,}000$ cubic feet per second, and the remaining flood-water of both rivers, about 500,000 cubic feet, (allowing 820,000 in all,) must be carried off by a land flood over a country which transversely to the course of the river is nearly level Allowing a depth of eight feet on the average to this flood, and a fall in the direction of the river of one foot per mile, about three miles of water-way will be necessary This therefore seems to be the width required opposite Coila Ghaut, and may be reduced as the channel of the Roopnarain becomes more capacious, and will cease where it becomes large enough to discharge the full flood without assistance

148 The sketch map shows the existing bunds, and it will be seen how badly they are placed for the discharge of a great body of water. The existing bunds to be removed are shown by a dusky shade, the existing bunds which need not be interfered with by a green shade, and the proposed new bunds in red. About nine miles of new bund will be required on the left bank of the Roopnarain and twelve on the right* To

* It appears probable that the Pattinan bund will answer for the line on the left bank south and a little north of the Midnapore road But nothing is allowed for this, as it is on the other hand also probable that the bunds on the right of the Dalkissore may require strengthening for some distance above the point where the new bund will commence

retain eight feet of water, these bunds must be eleven feet high, which, with three feet crest, and slopes of three and four base to one of height, give a Section of $(3 + \frac{7}{2} \times 11)\ 11 = 456{\cdot}5$ square feet or about 2,400,000 cubic feet to the mile Fixing the rate at three rupees per 1000 to cover the clearance of old bunds, the cost will be 7,200 Rs. per mile, or about $1\frac{1}{2}$ lacs for the whole twenty-one miles. Besides this expense there will be the removal of villages within the bunds, the loss of land-rent on about 50,000 beegahs, cultivated and uncultivated, and the adoption for about four miles of the Midnapore and Ooloobarreah road of a new line more to the south, if it be thought necessary to maintain this line.

149. It may however be observed that though the land not protected by the bunds (that is forming the flood channel) would be inundated in very high floods, it would not generally be so to any very serious degree, and might yield crops more often than not, also that the abandonment of three or four miles of the road between the Damoodah and Roopnarain was recommended by Captain Spens in 1851, because, even then, he did not think it could be safely maintained at a reasonable expense by reason of the floods.

150 An extension of the new bund on the left of the Roopnarain, as far northwards as the head of the Damoodah Khal on the right bank of the Damoodah, would probably be found advantageous, but it is not apparently necessary to the protection of the country to the south

151. The foregoing considerations appear to show the general nature of the operations to be carried out to protect the lower part of Mundulghaut, but it will of course be necessary to have an accurate survey with levels and a carefully prepared estimate before so important a work can be finally settled in all its details.

152 The levels of the survey (as far as it goes) show that there is no obstacle to the flood-waters running off into the Roopnarain and that the fears of a swamp being formed between the rivers are quite groundless. On the contrary the drainage appears to be better than the land-holders wish, for they construct embankments to retain the water on their lands. Under these circumstances any outlay for improving the drainage appears superfluous, and Government need exercise no interference with the operations of the cultivators, whose works can never stop the floods (Vide marginal note to the description of the Mundulghaut bund.)

153. The immediate outlay on this project in earth-work may therefore be roughly set down as follows:—

	Rupees.
Central Bund, ...	40,000
Mundulghaut Bunds, ...	1,50,000
Removal of bunds on right bank, ...	50,000
	2,40,000
Add contingencies and cost in first year,.....	24,000
Total, ...	2,64,000
On which the annual charges for interest and repairs may be taken at 10 per cent., ... } Rupees	26,400

154 The table given above showing the depth and velocity of the land flood in case of the bunds on the right bank of the Damoodah being removed, although referring to the case of the removal of the embankments on one side only, shows that the Embankment Committee of 1846 were very much mistaken in imagining that on the removal of the bunds on both banks "that it is altogether improbable that they [the floods] would rise above as many [2 or 3] inches"

155. The fact with respect to the floods on the removal of the bunds on the right bank appears to be, that they will have an extreme depth in different places of from six to twelve feet, and a maximum velocity of from three to five miles an hour, the mean depth and velocity on the whole varying in different places from three to eight* feet for the former, and from one and a half to three miles an hour for the latter.

156 But though such a flood would be a terrible calamity to bring upon a country which had never before been subject to inundation, and though it would in such a case be necessary for Government to pay in most cases the full value of all the property that would be endangered, and to remove out of the tract liable to inundation all towns and villages, the case is very different with the tract of land on the right bank of the Damoodah. The country there has always been liable to inundation. Captain Finnis, in his report of the flood of 1840, speaks of the country as being under water "as far as the eye can reach" Mr. Denton speaking

* The mean depth exceeds five feet only in one Section

of the country further south says that it was "one sheet of water, and that the water from the Damoodah passed over the bunds of the Dalkissore into the latter river". The villages are believed to be for the most part on mounds from eight to fourteen feet high, safe from the floods

157. Referring to the calculation of the capacity of the Damoodah Channel, to the discontinuity of the bunds opposite Burdwan, and to the above extracts from the reports of the flood of 1840, it appears evident that notwithstanding the breaches on the left bank at least 300,000 cubic feet of water per second must, in heavy floods, have passed down the low land on the right of the Damoodah, the whole flood discharge being 600,000 cubic feet per second Supposing therefore, that, the bunds being in existence, half the flood would pass over the low land that was calculated for on the supposition of the right bank bunds being removed, the result as respects the flood level will be as follows —

Flood Level

Section	Bunds Remaining	Right Bunds Removed	Difference
III.	183 7	185 4	1 9 feet
IV	172 0	174 0	2 0 „
V.	155 6	157 5	1 9 „
VI	139 3	141 2	1 9 „
VII	128 0	131 2	3 2 „
VIII	115 3	117 4	2 1 „
IX	106 2	108 4	2 2 „
X.	101 9	103 7	1 8 „
XI.	91 9	93 4	1 5 „
XII	87 0	89 5	2 5 „
XIII.	82 9	84 9	2 0 „

158 The effect of removing the bunds on the right bank, it therefore appears, will simply be, that the country will be inundated about two feet deeper than before, and the central bund being placed at the line at which the water would rise to two feet deep will leave exactly the same area of land liable to inundation.

159. Whatever the agreement between the Government and land-holders may be on the subject of embankments, it appears clear that the compensation to be paid on the removal of the bunds from the right bank of the Damoodah need not exceed annually what has before been

accepted for a year of heavy floods. The floods will on the average be deeper, and more frequent than before, but will not often be of the heaviest description, and in some years may not occur at all.

160. The calculations on which the foregoing conclusions are based have (with reference to the rough data on which they are based, and the ordinary uncertainty which attends such determinations of the discharge of running water) no pretensions to accuracy. Their results can only be looked upon as safe grounds for the conclusions by virtue of the margin allowed for errors, and from the circumstances of the case which render a considerable inaccuracy in the data, of very small consequence in the final result. for instance, in the calculation just made, it appears that a change of 300,000 cubic feet per second in the discharge of water makes a difference of only about two feet in the flood level.

161. The margin allowed in the calculations was stated before the results were given, and amounts on the average to 20 per cent. of the flood discharge. This appears more than sufficient to cover the possible loss of water-way from obstructions such as village mounds, &c, which may exist between the Sections of which the areas were taken, and to leave some balance of margin for any other causes of error. On the whole, in particular Sections there may be errors of one or possibly two feet in the flood levels, but from the margin allowed these are more likely to be in favor of the project than against it.

162 In allowing a continuous discharge of 600,000 cubic feet per second, it is further probable that the calculated exceeds the actual flood, in which that rate of flow is probably only attained for a few hours now and then during the most violent period of the flood.

163 It remains to examine how far for the relief afforded to the country by the abandonment of the embankments on right of the Damoodah will be permanent.

164. The flow of the flood-water over the right bank of the river will commence probably about Sungutgolah and will continue twenty miles down the stream. The water passing over this bank will diminish its mean velocity from about six or seven feet per second in the river to about three or four on the low country, and may possibly deposit $\frac{3}{4}$ of its suspended matter in consequence. The deposits, which have raised the river's bed lower down, do not, it appears from the lower Sections, extend more than two miles inland from the bank, consequently $\frac{3}{4}$ of the solid matter held in suspension by the floods might possibly be

deposited on the right bank over about forty square miles. Referring to the former calculation on this subject it, will be seen that this would give an average rise of the right bank of $\frac{12{\cdot}75}{40{,}000}$ or about 0·32 of a foot per annum. The difference in level between the right *bank* and the lands on the left of the river appears on the average to be about eight feet, so that at the above rate the bank on the right would become as high on the bunds on the left in about 25 years on the average, or 13 years at the river edge of a sloping Section. The process might actually take 50 or 100 years, or the deposit might form partly in another position, and after the bank had risen on the right in the 20 miles below Burdwan, the surplus flood-water would still find a passage on the right bank lower down But however this be, it is plain that the removal of the bunds on the right bank of the Damoodah cannot be looked upon as a final measure.

XI General conclusions

165. The foregoing observations appear to show that no permanent or satisfactory improvement of the Damoodah so as to secure the country from floods can be made by confining the river between embankments on or within the sites of the present bunds, or between embankments retired to a greater distance, or by new channels.

166. The other modes of remedying the existing state of things which have been mentioned are.—first, lengthening the course of the river so as to reduce the declivity, which the calculation of the cost of a channel to carry off only two thirds of the floods, for a length of only 15½ miles, shows to be utterly impracticable; second, by forming rapids or weirs, to reduce the declivity of the intermediate spaces, which also appears impracticable owing to the great expense of the works carried, as it would appear they must be, over the rivers and streamlets of a very large tract of country, including all bearing down sand to the main river, and the measure when complete will only be preparatory to the final object, the improvement of the lower part of the Damoodah, and third, the construction of reservoirs.

167. As the greatest floods of the Damoodah appear to last not more than four days, during which a discharge in round numbers of 200,000 million cubic feet of water takes place, reservoirs to hold 100,000 million

cubic feet would enable us to reduce the violence of the floods by one half when at their greatest, and altogether prevent danger to the country from the more moderate freshes. 50,000 million cubic feet of the contents of the reservoirs might perhaps be retained at the close of the rains, and poured off gradually down the river in the dry season, which would not only serve in some degree to clear the channel of deposits, but would make it navigable.* There appears to be no doubt that sites for the reservoirs† could be found in the country along the 185 miles of the Damoodah's course (and 140 miles of the Burakur's) West of Burdwan. The expense however of the measure would be great. Colonel Dixon's reservoirs in Ajmere and Mhairwarrah cost (including masonry dams, escapes and sluices) Rupees 150 per million cubic feet of water, which for the 100,000 millions to be retained would come to one and half crores of Rupees as a first cost, and would besides require further works on the river, and considerable annual charges. Such an expenditure may be thought too great to be laid out on the improvement of the Damoodah alone, and the practicability of this scheme seems therefore to depend upon the possibility of getting the water used for irrigation, and adequately paid for by the cultivators. At all events an immediate remedy for the present state of things does not appear practicable in this way.

168. No immediate permanent and complete remedy for the liability of the country to disastrous floods appearing possible, nothing appears to be left but to adopt Lieutenant Beadle's scheme of applying a partial remedy in removing the bunds from the right bank as discussed in Section X of this memorandum. It has been shown that the injury which will be done to the country on the right of the Damoodah by the adoption of this scheme is by no means likely to be so great as has been supposed, and that the country on the right bank will not suffer much more from the heaviest inundation, after the removal of the right bank bunds than it always has done hitherto, but the injurious effects of moderate floods will be somewhat greater, and they will more frequently inundate the country.

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* 50,000 million cubic feet, or one day's flood at 600,000 cubic feet per second, gives a discharge of 2,000 feet per second, for 300 days.

† At an average depth of 10 feet, they would occupy 370 square miles of surface about one-twentieth part of the drainage area of the rivers, or less if a greater average depth could be got.

169. The measure, it has been seen, will not afford any considerable increase of security to the country on the left bank West of Burdwan, in which portion the bunds must be strengthened; but from a few miles East of Burdwan, downwards, the country on the left of the Damoodah will be completely protected from the inundations of the river, and the cost of the works to be constructed is very moderate.

170. It is true that we cannot calculate upon permanence in the improved state of things on the whole which will ensue; but as the improvement will in all probability last for many years, and as there will be, meanwhile, opportunity afforded to watch the effects of the floods and to devise further measures, which may result in still greater improvement, this objection appears to form no reason why the measure of relief afforded at so small a cost should not be at once applied; such at least appears to be the conclusion as far as Engineering considerations affect the question.

XII. Specification of the works required.

171. If the Board approve of these views, the following are the works to be recommended. There appears to be no reason why they should not be completed in one season, and if estimates be considered necessary, they might at once be called for, so that the work, if sanctioned, may be put in hand early after the ensuing rains.

(1.) The formation of a flood channel contained between bunds right and left of the Roopnarain to carry off the flood water from the country between Omptah and Goopeegunge with safety to lower Mundulghaut. Sections of the country should be taken, running East and West from the Damoodah across the Roopnarain, and three miles beyond it, the Sections being about two miles apart.

These Sections should be connected by a line of levels down the Roopnarain, and should terminate South, where the Section of the river (making allowance for tides) becomes sufficient to carry of 800,000 cubic feet of water per second. Above this the bunds should be laid out so as to carry off in the channel between them, and with the assistance of the river, the same quantity of water without inundating the country to a greater depth than eight feet at the line of bund. A map should be drawn, showing the levels, and the lines of bunds (on both sides of the Roopnarain) proposed for adoption, and the improve-

ments required to existing bunds, as also the position and the extent of the villages to be removed into protected ground.

Copy of the sketch-map and the portion of this memorandum referring to the work should be furnished to the Executive Officer.

(2.) The construction of the central bund. The Executive Officer should be supplied with a copy of the sketch of this on the map of the survey, and with the levels where the line crosses the Sections of the country. He may be desired to fill in the details, giving the crest a regular declivity between the fixed points of level, and placing the embankment on the best line, chosen after personal examination of the country. He should supply the necessary drainage sluices.

(3) Removal of the bunds and other obstructions to the escape of the water over the right bank of the Damoodah, from a little above Sungutgola to about 10 miles below Burdwan, that is, to the angle where the river turns South. For this distance every thing should be removed which will afford obstruction to the water in reaching the low ground South of the river; but if motives of economy or considerations connected with the convenience of villagers should require that any mounds or other obstructions be left, the Executive Officer must make up for the loss of water-way by carrying his operations further down the river, so as to have at least 20 miles of clear water-way over the right bank between the site of the present Sungutgola bund and the termination of the clearance.

172. A Report on the bunds on the left bank from Burdwan Westwards, with the necessary levels of the crest of the bunds, the river, and the adjacent country, appears to be required to show what further measures may be necessary to secure the protection of the country from floods.

173. Copy of the map and such portion of the foregoing information as may be useful to the Revenue Officers, may be sent to the Board of Revenue.

(Signed) C. H. DICKENS.

28*th November* 1853.

(True Copy,)

C. H. DICKENS,
Offg. Assistant Secretary, M. B.

Extract of Colonel Sim's Report on the Coleroon Annicuts, dated 16th July 1839. Madras Engineer Papers, page 131.

The river Cauvery, which has its source in the Western Ghauts, and flows past Seringapatam through the Mysore and Baramahl countries, separates into two streams at the island of Seringham ten miles to the West of Trichinopoly, and about hundred miles from the Sea. The river above the point of separation is termed the Agunda (broad) Cauvery, the Southern branch, which flows through the Tanjore Province, the Cauvery; and the Northern branch, the Coleroon. The latter river, which is considerably the larger of the two, and irrigates a comparatively small portion of country, has a free uninterrupted passage to the Sea, continuing throughout its course a large and powerful river, while the Cauvery at the distance of twelve miles from its head, begins to throw off branches, some nearly as large as itself, and is speedily reduced to an insignificant stream by the endless number of channels and water-courses which are drawn from it as it proceeds, for the purposes of irrigation.

The current of the Coleroon, from its straight and free course and the size of its stream, is sufficiently powerful to preserve its channel comparatively clear, and great part of the mud and sand with which its waters are charged; are carried into the Sea, forming opposite to its mouth, an extensive bank known by the name of the Coleroon Shoal. But the Cauvery is very differently affected. Being the smaller river, and flowing on a high level, banks of sand are left at its source after every fresh; its stream diminishes in size and velocity very quickly; and the sand and mud carried into its channel are deposited as soon as its water becomes tranquil, forming extensive accumulations along its course which obstruct and retard its current. It is manifest that the inevitable consequence of this state of things must be the progressive rise of the bed Cauvery, and necessarily a progressive diminution in the proportion of water which enters in at the separation of the two streams, terminating ultimately in the annihilation of the river, if nothing intervened to modify and retard these effects. It may indeed appear wonderful that this catastrophe has not arrived, considering the very great quantity of earthy matters brought down by the river during freshes, of the extent of which some idea may be formed, from the size of the shoal opposite to the mouth of the Coleroon. Colonel Caldwell, who first examined the rivers with care in 1804, was forcibly struck with the

unusual character of the Cauvery, and predicted its total annihilation at some future period, unless the river could be restored to what he believed to have been its original condition. But the evil, though progressive, is much slower than might at first be expected. The sand and heavier ingredients are deposited in the bed of the river, but a considerable portion of the firm soil, from its less specific gravity, remains longer in suspension, and is ultimately carried into the smaller channels, and from them into the rice fields, which it greatly enriches. A part of the sand is also occasionally removed by manual labor from the bed of the river, but the most powerful remedy in this as in other cases, is provided by Providence, which has so ordained that evils when they attain a certain height often work their own cure. In the present case, as soon as the channel becomes so much choaked with sand that the stream is greatly obstructed in particular places, the first unusually high flood, and such floods seem to occur once every ten or twelve years, never fails to overflow and destroy the banks in many places, and through the breaches an enormous quantity of sand is swept, and the bed effectually cleared and deepened for miles. These remedies, it is true, are irregular and partial, and accompanied often by extensive loss of property, and damage to the country, but they have had the effect of hitherto retarding the consummation of a much greater evil. The channel of the Cauvery has, however, continued to rise, notwithstanding occasional interruptions from the above causes, and with it, the adjoining land on both sides has also been raised, by slow but constant accumulations of soil deposited on it from the river through breaches, by manual labor, and the sediment of the muddy water of the freshes, so that the course of the river to the sea is now along nearly the highest ridge of land in the Delta, instead of having followed the lowest as is the case with rivers generally. The land, no doubt, was originally the lowest, but it has gradually been raised, and the river with it, by the causes above specified.

(True Extract,)

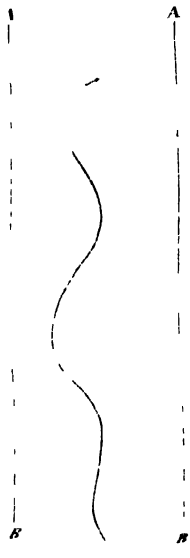
C. H DICKENS.
Offg Assistant Secretary, M. B

COLONEL GARSTIN'S MINUTE.

[*On the Superintending Engineers' Inspection Report*]

As far as the maps go, I can follow Lieut.-Colonel Goodwyn in his descriptions of the state of the embankments, but from Muskara no plan or map has been sent showing the Zumeendaree Embankments, so that I cannot follow that part of the report properly.

The 9th para. is the first which requires notice, not that I am prepared to say that the line of New Embankment from Jalalpore to the Canna Nuddee is the best, but I am of opinion that Lieut.-Colonel Goodwyn is not right in wishing to have the embankment too close to the river. If there never had been any bunds and new ones were to be made, I would



place them as in the margin one mile or more from the nearest point, thus giving an ample margin in addition to the bed for floods which would then only impinge very obliquely on the bunds, constructed as they now are, they must constantly be perpendicular to the course of the river at some of its greater sinuosities. It is true a good space of land will always be inundated if made as in the margin, and no villages should be built there, but the land is so well manured by the deposits that it is more profitable than that behind the bunds and gradually rises. In the present case I admit Selimabad and Jumalpore are not protected by the new bund, and it may be worth repairing the old bunds and sloping the banks to protect these villages. In Lieut.-Colonel Goodwyn's plan of this part, the village of Jumalpore is most accurately laid down, and shows at least that that portion of the bund could not have been taken nearer the old bunds with safety, and by an article in to-day's paper, contradicting the lies in a former paper, it is most distinctly stated that the new line was taken to save, if possible, or, at any rate, to avoid pulling down houses, temples, filling tanks, &c., as long as it could be done. Why the old bund on each bank of the Canna Nuddee stops short as it does in the plan I cannot understand, it might be continued to join the new bund. If the bund behind Jumalpore could not be carried further in advance, it is probable the bund across the nullah could not have been placed in a better position, but this requires a local knowledge I do not possess. The

old bund, if continued to the new one, or right bank of the Canna, might in a slight inundation stand, but from its position being so very much exposed to the whole force of the river, it probably would give way even if no other bund was breached, but on the opposite or left bank of the nullah it might protect all that land between the old and new bunds from the back water.

It is unnecessary to follow the report paragraph by paragraph, because local knowledge alone can decide what is required at each place, and we must not forget that what would be perfectly right if it was a new question of bunds, may not now be always just.

I do not approve of the lines of new bund constructed last year from Culna to Debdara and from Debdara to above Mohunpore, the line should have been straight from Culna to near Mohunpore, for the very reasons stated in 11th para., the points of junction of the old and new bund being very weak. The breaches in the portion between Mohenpore and Nissendpore were probably *cut* as they are situated where no direct action of the river could take place. The line from Dagrah to Mohunbuttee should, if not carried straight to Champadungah, at least follow the dotted line, avoiding the sharp angle at Mohunbuttee. The very narrowness of the river between the bunds at Suntospore shows that even the freshes, where running straight with the bunds, do not break them when properly made. How so large a space and so far from the edge comes to be without any embankment as appears to be the case at Die Tigree I know not. The new line from Champadungah to Muskara runs very nearly parallel to the course of the river, and needs no remark; but the bunds on the Mundorea Nullah are the most extraordinary bunds I have seen, evidently made by the Zumeendars to include particular fields, whereby twice as much work has been done as would have been required had they been made straight, and so many more weak points created, for when the inundation came it would find hundreds of small points opposed to it directly, though the whole line is oblique! this shows that no Zumeendar should be allowed to make any bunds. It also appears that from Akna there are no more bunds on the right bank of Damoodah, and at Rajoipore, no more on the left bank of the Damoodah Khal, and at Subainpore, on its right bank, and at Hurripore, on the Gojah Khal.

I have no doubt that the remarks on the right bank of the Damoodah are correct as well as those on the portion of bunds in the Midnapore

district, but having no maps showing the bunds in Midnapore, and not knowing the localities, I cannot judge, and I can only say that Colonel Goodwyn's description of them is very bad, and I should call on the Officers in charge to account for this, particularly as far as it refers to the Zumeendaree bunds which are under their inspection, and I would send this part of the report to the Board of Revenue, and suggest that all Zumeendaree bunds be transferred to the Executive Officer, and those not required levelled, and that in the new Regulations a clause be inserted strictly prohibiting the construction of any bund without the previous sanction of the Executive and Superintending Engineers.

So much for Part 1st of Lieut.-Colonel Goodwyn's report. I am not aware of any tributary stream entering the Damoodah below Burdwan till near Bandah where the Damoodah Khal, which may have received water from the Dalkissore, rejoins the Damoodah and the Mandoria Nullah at Omptah, and the Musraka at Musraka, the two latter being merely large drains of the country and not, like the Damoodah, rivers rising in hills and subject to great and sudden rises called freshes. Lieut.-Colonel Goodwyn's 5th para., Part 2, is at variance with his line of argument for keeping up the bunds on both sides, for the greater the body of water admitted and the more sudden its admission, so much more likely, according to his argument, would it be to scour the bed, and sluices would prevent this on the large scale, though they might increase it for a short distance and in a short breadth. There can be no doubt that sloping the bank will prevent its being undermined as steep banks are, but still they will be liable to erosion. No bund can be made in one year, however well constructed, it will sink a fourth or fifth, if constructed in moderate rain, it will be better consolidated than any ramming could do, but earth-work cannot be raised in excessive wet weather, nor will a bund that has not got dry to its core resist the action of water. The proposed plan for ascertaining the flood level is an excellent one and does great credit to his ingenuity, and, if well made, must give correct results. The question of the Zumeendaree Embankments is one that must be quickly settled, and is not unfairly put in the report, and it is so obvious, that, until this is put an end to, no dependance can be placed on Government Embankments, which must fail if the neighbouring bunds fail, or at any rate they are useless if the country is to be flooded from the neglect, avarice or parsimony of the Zumeendars or Putneedars, who get a remission of revenue for keeping up the bunds, but do nothing.

So much for the preliminary remarks on the report I now proceed to the 3rd part which contains the pith of the whole matter, the real question is as to the policy is keeping up Embankments and the best way of doing it under present circumstances. The first point has been agitated from time immemorial, and is yet as far as ever from a satisfactory decision Volumes have been written, and the most contradictory assertions made, and conclusions drawn from them, with the most perfect conviction of their truth, yet it is evident all cannot be right; the fact that no rule or law has been discovered by which the effects of running water can be calculated, and the utter impossibility of foreseeing the results when an accumulated body of water breaks the obstacles which retained it, has led to much discussion, and various plans to try and remedy the evils consequent upon these accidents, and as in every instance these have arisen from some local circumstances, so localities themselves have had a greater or less beneficial or inimical effect on the schemes proposed.

The question as it now stands in regard to the Damoodah bunds is not a simple Engineering one it is affected by the artificial interests which have sprung up by the advance of society, the increase of population and commerce, &c, and the threatened destruction of the town of Burdwan, the Grand Trunk Road, the Rail Road, and the silting of the River Hooghly by which the external commerce of the country reaches Calcutta, these are objects of so much importance that they may force the continuance even of a vicious system.

Three principal proposals have been made regarding the bunds of this river—*first*, to destroy all above the reach of salt water, *secondly*, to abolish those on the right bank, in order to protect Burdwan, the Grand Trunk Road, the Rail Road, and the Hooghly, and *thirdly* and *lastly*, Lieut.-Colonel Goodwyn's project to raise such efficient embankments on both sides, that the river shall be forced to carry all its water and detritus into the Hooghly at Pultah.

Now let us examine what would be the probable effect of each of these plans, and in order to judge of the probable effect of the first, we will look to other rivers, in this country, rising almost at the same spot in the same mountainous tract as the Damoodah, and in other localities of a similar nature, and consequently all subject to the same laws.

The Soane, the Morhur, the Fulgo, the Poonpoon, and other smaller streams rise nearly together and close to the source of the Damoodah,

and after heavy continued rain invariably rise over their banks and cause inundations; the Ganges, Coosey, Mahanuddee and Burrampootra and a number of smaller streams all rise in the Himalaya chain, and are therefore equally subject to the same laws, and inundate the country they flow through, yet none of these are bunded; and what is the consequence? The villagers know where, and to what extent, the waters will rise, and are prepared for it, and little or no injury is done to the country, for the waters run off as quickly as they rise, and leave a rich deposit behind them. If we look at the map we shall find the Dalkissore and Roopnarain and various other streams run, I may almost say parallel to the Damoodah, and rise in hilly districts, and they are not bunded; yet the country is well cultivated and populous, and no claims for remission of revenue are ever made in consequence of the annual inundations. It therefore is doubtful whether the Damoodah embankments have not been very injurious to the country, from confining the large body of water till it has risen high above the level of the country, and until it bursts the bunds, and causes great loss of life and property to individuals, and revenue to Government.

In 1850, when two extraordinary inundations took place in the Gya district by the overflowing of the Morhur, Poonpoon, Fulgoo, &c, carrying away the part of the road between Gya and Patna, I had an opportunity of seeing the country just as the waters subsided, and I marched not only along the whole road to the Grand Trunk Road, being thus enabled to compare the country on each side of the road, but across from Gya to Tiparee and thence round to Patna, thus twice crossing the whole breadth of the inundation, for the whole of this tract except villages had been more or less under water, but as there were no bunds until we came to the road (which was *de facto* a bund). The waters spread quickly over the country, and the inundation though from ten to twenty miles broad was shallow, and with very little current except in the beds of the rivers, so that it did no injury, not even destroying the rice crops, and I was forcibly struck by the fact that where no obstacles opposed the flood, few marks even existed of its having passed over the country. The road was, however, totally destroyed, as the inundation took a turn direct on the road, which stopped the water till it collected, overtopped, and destroyed it, and several of the bridges and drains. In 1821, the Burral river burst its bunds between Nattore and Bauleah, and I was sent up to report on it, and recommended the abandonment

of the bunds, and that large breaches should be cut at short distances to allow the water to flow freely over the country, and that notice should be given that the bunds would be abandoned at once; this was done, and the effects were that the villagers knowing where and to what extent the next year's inundations would reach, were prepared against it, and no complaints or remission of revenue have since taken place. I had an opportunity in 1841 of examining its effects over a large extent of country after 20 years, and found large tracts had been raised, and in some places mulberry trees were growing where formerly rice grew, and there can be no doubt that, with skill and capital, vast tracts of jheel and swamps might be gradually reclaimed, by retaining the water at certain seasons until it had deposited its silt, and then letting it off.

Here we have two instances in which I have seen and remarked the result of inundations of rivers without bunds similar to the Damoodah, on a large scale, and it would be very easy to carry this comparison all over the country, for except the Gunduck and the rivers in the districts about the Damoodah, and in 24-Pergunnahs, and a part of the Bagaruttee, and isolated parts of the Ganges, I am not aware of any other bunds in this part of India, yet we all know how the Burrampootra, Ganges, Coosey, Mahanuddee, and many other rivers annually flood their banks to a greater or less extent, and no damage is done by it To show how the natives will protect their dwellings, I need only say that, going from Dacca towards Tipperah, near Naraingunge, we see villages raised as the Burmese houses are (and as is common in Assam) on posts, and the river flowing under them many feet deep. I mention these circumstances to show that if proper notice was given of the abandonment of the bunds on both banks of the Damoodah, it is not likely to be attended with any disastrous effects either to the country or its inhabitants, and I am of opinion that considering the immense space of country on both banks over which the waters would simultaneously though gradually spread, that even when the waters reached the Grand Trunk Road or Railway, they would be so shallow and have so little current that they would cause no damage to either.

There are, however, other arguments which must be examined, and on which much stress is often laid, and effects attributed to them which are very doubtful. All rivers like the Damoodah, rising in hilly countries, are liable to sudden rises after heavy rain in the hills, and they then bring down stones, gravel, sand, and silt, the first seldom go far, nor does the

coarse gravel, but the sand and silt are carried to the Sea. Now although this is an undisputable fact, it must not be supposed, that the sand is carried down at once, for, on the contrary, any body watching the shifting of the sand banks in the Ganges, will see a large bank disappear one day and another will be formed a few miles lower, and continue perhaps for years, but every year, and often at all seasons, similar changes take place, but particularly in the rains, when the rivers bring down an immense body of water and have a rapid current, these shifting of their beds are constant, and thus the sands are gradually pushed on to the Sea, and often the slightest obstacle will cause a total change of the river's course. I cannot give a greater proof of this than what occurred a few years ago in the Burrampootra at Jumalpore. At this part the river took a sudden turn, very like that of the Damoodah at Selalpore, sending off a small branch called the Jenai, but the principal body of water went past Jumalpore and Mymensing, and so down towards the Sea, and it was as large a river as the Ganges A boat was accidentally sunk nearly at the turn, and an immense sand formed over it, and the great body of the Burrampootra now runs down the Jenai, and I have walked dry across the old bed of the river between Jumalpore and Mymensing in the cold weather, though in the rains of course a good deal of water still finds its way down the old channel I said that these sands were seldom carried far at once, and are generally deposited in the river's bed, and not on its banks, except where bunds have been formed If any one will take a bucket of Ganges water, or even Hooghly water, in the rains, and allow it to settle, they will find little or no sand in it, though about two cubic inches of silt in one cubic foot of water, because though held suspended in the water during its freshes, the sand is never at the top but always low down, and it is only where sudden turns of the river force the mass against the bank that it has a tendency to throw some sand over the bank, a careful examination of other unbunded rivers will clearly establish this, and if we examine the Section of the river's banks, we shall generally find them pure sand below, and the deposited alluvial soil or silt above, which in time becomes cultivated.

Lieut-Colonel Goodwyn quotes Major Rennell to show that inundating rivers occupy the highest parts of the tracts through which they flow. Major Rennell was a great man, but I do not admit this fact as established even on his authority, for it is positively against the nature of water which seeks the lowest levels, local circumstances may occasionally for

a time force a torrent over ground that is not the lowest, but the cause of the banks of rivers being generally slightly higher than the land further off is (and would be the same if the river flowed as they generally do through the lowest level) correctly stated, and the silt is deposited as soon as the water rises above its banks, because it is shallow and its velocity decreases, and this depositing of silt always commencing at the edge of the river, and decreasing as it extends, naturally alters the level of the country slightly, but I am not inclined to admit that the Damoodah being higher than the Hooghly or Roopnaram, is a natural fact, but that it is the probable effect of the system of bunds which have for so long a time existed on it, and the destruction of the road near Oolabaria quoted by Colonel Goodwyn, arose from the bursting of the bunds when they had raised the level of the river high above the adjacent country, had there been no bunds, the road would not have been injured by a simple inundation

I perfectly agree with Major Baker that it would be dangerous to admit the water of the Damoodah into the Hooghly, and my reason for opposing the cutting of the Canal from Selalpore direct to the Hooghly (proposed by the natives who offered to pay for it) was, that the sands brought down by that river would be deposited in the Hooghly and destroy the port of Calcutta That such would be the probable effect of admitting the waters of the Damoodah into the Hooghly, either above or below Calcutta, is more than probable, for, judging by the effects of letting the Ganges into the Bhageeruttee at Sootie, and the increased quantity of sand brought down by the Adji in consequence of the clearance of the Jungle Mehals, similar results though in a much greater degree would follow the admission of the Damoodah History tells us that 100 years ago Admiral Watson took a 64-gun ship up to Chandernagore, (with difficulty, it is true, but he did it,) now a small brig could not get up, for a large sand bank has been formed opposite Chandernagore, another near Barrackpore, and others in other parts, a similar deposit now covering with silt has been formed opposite Shalimar and the Bishop's College, and in various other parts of the river have changes taken place of late years owing to the sands now brought down and deposited in the Hooghly in greater quantities than formerly

I admit that the James and Mary is formed by the collision of the waters of the Hooghly and Roopnaram, the former, however greatly assisted by the Damoodah in the rains, when it brings sand with it, and

forcing the current of the Hooghly to the left bank, instead of allowing it to go fairly down its whole channel, and aided by the projecting left bank, making the opposition of the rivers more direct, and causing a great back water between the Damoodah and Roopnarain under the right bank. Moreover, the changes at this point are now so constant, that it is daily surveyed, and no Pilot is allowed to quit Calcutta without seeing the last survey report. The sands on it are said to be quicksands.

The second proposition is to abolish the embankments on the right bank, so as to allow of a great and free dispersion of the water over the right bank, and, by strengthening the bunds on the left, to protect the portion of the country which has suffered so much when the bunds gave way, or were cut, and by which the Grand Trunk Road was rendered impassable, and bridges destroyed, and which, it is apprehended, would also injure the new Rail Road, and there can be little doubt, that if the bunds on the left bank, are made of a proper Section, and the banks sloped off these measures would be sufficient. The necessity of sloping the banks is evident from the fact that the bank being sandy below, with a bed of soil above, the water penetrates and saturates the sand, till it is incapable of supporting the superincumbent weight of earth, which then falls in; and the erosion of the bank adds large quantities of sand to the existing obstructions in the river, and in addition to what the floods bring down.

Now, from the remarks of the Superintending Engineer in his Report, it is very evident that the bunds on the right bank are not, and never have been, in a proper state to resist the inundation, and have always been easily breached, and that the Zumeendaree or Kurritah bunds, can scarcely be said to exist at all, consequently the total abandonment of the bunds on this side, cannot be attended with that hardship that might have been felt, had they always been kept in an efficient state; besides though the country is populous and well cultivated, but little mischief will follow the destruction of the bunds, whilst there are no large and rich towns like Burdwan, and no important public roads like the Grand Trunk Road, or Rail Road, requiring defence, and if any sand was carried into the Dalkissore or Roopnarain, it would not interfere with the navigation of those streams, for only a few small boats, and those chiefly for fishing, exist on them; and there will be less fear of the sands of the Damoodah entering the Hooghly. If such a misfortune occurred, in a very few years, not a ship would be able to come up the Hooghly, and Calcutta would be ruined as a port, and great injury and loss would accrue to the commerce of the country.

It is connected with this scheme that the proposed cut from Sungutgolah to Jumna was ordered by the Board, to take the set of the current from the left bank on which it impinged directly at Ragubpore, and where it is within a few feet of forcing its way into the Banka Nullah, which flows through Burdwan, and, if this occurs, the probability is that very great changes would take place in the Banka Nullah, and in all probability the town of Burdwan would be destroyed. It is useless speculating on what might occur to Burdwan, in such a case, as it is impossible to do more than guess at its probable results; however I conscientiously think, every thing should be done to prevent it. Now the piling made in front of the bank at Ragubpore, is so directly opposed to the set of the river, that it is neither impossible or improbable that it may be carried away, it may be strong enough to resist the force of the stream, but the bed being sandy, it may not be able to resist the river, when it scoops away the sand of its bed, in which the piles are driven, and, this was one of the objections to Lieut.-Colonel Goodwyn's bund; it would have been equally and directly opposed to the river with only two feet foundation on the sands, and nothing to prevent the river destroying its own bed. Its cost, too, was to be Rupees 4,50,000, whilst, I believe, the cut proposed by the Board would not have been Rupees 80,000, though we said Rupees 150,000, taking a wide margin. Again, in regard to the proposed cut, I am satisfied the Superintending Engineer, did not begin the work in the proper place, the line laid down by the Board on the map would have carried the cut to a natural water-course, which lying in a valley, would very soon, and at no expense, have made itself a sufficient channel to carry off a large body of water. However the thing is now of little importance, Government having decided that it should be abandoned. The bund across the Canna Nullah should be either made a puckah escape dam, or else the bund should be so strong, and carried so high over it as to form a continued bund, with those on the sides, and prevent any water going over in that direction.

We now come to the third or last project. If a breach in the bunds was an impossibility, then Colonel Goodwyn's plan would be excellent, but whilst slight accidents (even a rat-hole) render breaches constantly liable to occur, (leaving out the other objections attendant on it,) the remedy as proposed is, I think, worse than the evils it is intended to avert. In my remarks on the first part of this report I have made some observations on the new lines of inner bunds which are decidedly better than the old

lines following the sinuosities of the rivers, though I do not altogether approve of them as I think they would be better if carried straighter and farther inland. The objection made by him, that making the bund far inland leaves a considerable space entirely exposed to the floods without any protection, is quite true, and it would be advisable to remove all villages inside of the line, and for a time at least, some inconvenience might be felt by those so displaced, and perhaps some rice lands would be lost, for that species of cultivation; but so near such a market as Calcutta, this would be amply repaid by the increased fertility of those lands caused by the deposit of silt, which would enable their owners to grow various other crops after the rains, which would be more productive than rice, and it is also necessary to put the bunds some distance from the edge of the river, to assist in relieving them of the weight of the increased body of water suddenly accumulated, which, it is evident, will be better done the further they are off, for the area of the space above the bank, and between the edge of the river and bund, will probably be fully equal to the Section of the river in its bed, and consequently double the latter, whilst the rush of the inundation would act obliquely on the bunds, whereas at present, at every sudden turn, the river comes down perpendicularly on the bund, and when this is close to the bank, it must be very strong to resist it, and generally gives way.

The river may be clear enough, and totally free from sand, in the cold weather, higher up, and where the stream does not run under the bank, but between beds of sand, it will not corrode its banks. Colonel Goodwyn is, I think, mistaken as to the effects of the confining the river in its freshes.

In the first place it will have a great increased tendency to disturb its own bed, nor will this prevent its depositing the sand thus raised, for this substance is not held in solution, but in suspension, and the coarser particles are at the bottom, and naturally from their own weight are inclined to settle at almost every turn of the river, indeed, wherever there is a back water, there will a deposit immediately take place, or where any obstacle, such as a tree or sunken boat exists, a bank will often be formed in an incredibly short time; supposing the bunds made as suggested, it is highly probable the sand would be carried quicker to its end, but still not at once as he supposes, indeed he confirms what I have said, for instance in his 7th para where he refutes the assertions of the annual rise of 7 inches in the bed of the river, for he admits the sands where the Sections had been

taken *had shifted to be replaced by others*, and this is exactly the way in which, as I had observed, the sands of the Ganges were gradually carried on, till they reach the sea; but in all tidal rivers where the tide meets the freshes, deposits are more quickly made, and on a larger scale, and often as rapidly removed, as are instanced in Edmonstone's Island, and the large Island thrown up in the Auckland Channel. Now although if these bunds were formed, and stood firm, the shiftings and transport of these sands along the bed, and to the mouth of the river, might be accelerated, (and if there were no bunds they might be retarded,) of what consequence would this be? If the river was navigable, then I admit it would be an object to keep it open, but the Damoodah never was, and never will be, a navigable stream, it is literally nothing but one of the great drains of the country to carry off and disperse the waters which invariably fall in hilly countries in greater quantities than in the plains, and bring down large quantities of silt, as well as sand, which helps to fertilize the land, and forms Islands in the Sea, which recedes as the land advances. Now it is well known that, since the bunds have been made on the Gunduck, whenever there has been no breach on the bunds, (generally when the rains have been scant,) many of the wells in Sarun were very short of water in the hot weather, and in many parts, lands, which benefited by the inundations in former years, are not so productive as formerly, the natives rarely manuring any but their poppy, or mulberry fields, and the heavy rains of this country with the overflowing of rivers alone enable the lands to imbibe and retain a sufficient quantity of moisture to render them productive, otherwise they would, from the great heat of the sun, become barren and soon burnt up.

The volume of water that passes down, is more a matter of curiosity, even if the calculation was correct, than one of any utility in the present instance, and the velocity of its current might (depending as it does on its fall) become a matter of importance were the waters of the Damoodah required for irrigation purposes, as in the Upper Provinces, but this too is not the case here. From the information now obtained, dividing the river into four parts, it is easy to see that in the first the current must, from its greater slope, be more rapid than in its second portion, but as this is on an average twice as broad as the first part with half its fall, the body of water flows off at nearly the same velocity, for the velocity is as the versed sine of the slope, and the pressure of the rear water is diminished according to its slope, for were this not the fact, in the third

part when it contracts to one quarter of the breadth of the second, it would run with four times the velocity, but as the slope is diminished again about one-half, the current does not in fact very much increase in its velocity there.

In the fourth part, it is tidal, and there is unquestionably an under-current always running down, even when the upper or tidal current runs up, and it is evident that in the rains though the tide does not rise at the top, and ships generally swing to it, yet so small a body of water comes up with the tide, that when the freshes are strong, the upper surface is not able to make large ships swing, their lower parts being acted on more powerfully by the under-current, which carries the sand in suspension towards the Sea.

I have examined the Po, and in the summer, the bed of the stream is not raised above the adjacent land: it is in winter, or after heavy rain, even in summer, that it rises nearly to the top of the bund. Now the Po is not a larger river than the Damoodah, but deeper, and flows not through sandy plains, but through some of the most fertile soil in Europe, yet the fact is not to be disputed that the river, and its tributaries do carry sand, and deposit it in its bed, though very slow; or why have the embankments been gradually raised? Now if Colonel Goodwyn's theory is correct, this would be impossible, for not only are no waters drawn off from it, but it receives a great accession of water from its tributaries, of which the Reno, Savena, Idice, Silaro, Santerno and Senio, are all of considerable size, besides several other torrents. Consequently the Po, with so great an advantage in the immense accumulation of water in its freshes, ought not only to keep its bed clear of deposits, but actually render it so much deeper, as to require no bunds at all, yet this is not the case, it has bunds, and these bunds are constantly increasing, and its bed is full of sandy deposits Lieut.-Colonel Goodwyn is also mistaken as to the Lamone, as this river did not enter the Po di Primaro, but debouched into the Sea, and however calcareous its deposits in its higher parts may be, it decidedly carried sand in the lower parts so that the embankments have been greatly raised of late years, and it has done great mischief, whenever it has burst its banks. Many observations were taken in the middle of the last century, to ascertain the actual condition of its bed, and it was found that the bed of the Po remained stationary in many parts of its course for several years, and that sometimes it deepened, sometimes raised it again, as it might be effected by the freshes in any

one of its tributaries. In fact the great Po, though abounding in water, has never occupied a fixed bed, until after having ceased to flow over a gravelly bottom, it no longer received from its tributaries any other matter than sand, and after this frequently it changes its bottom as affected by local circumstances, though upon the whole the necessity of gradually increasing its embankments, denotes a general rise, (though perhaps imperceptible,) in its general bed. Now the Po carries much more water to the Sea all the year round than the Damoodah, and is always subject to freshes, and the latter never, except in the rains, still the rivers have so great a similarity, that we may safely calculate that the same results caused by the same effects, will occur in the one, that have occurred in the other, though perhaps not in equal periods of time; but there is this difference that the Damoodah not being a navigable river, the corrosion of its bed is of little consequence, for when the Rail Road is finished, all the coal will come by land, and not by water. I totally differ with the Superintending Engineer as to the effects of what he calls Major Baker's proposal of doing away with the bunds on the right bank, (it was proposed at the Board long before the letter was written) He says he knows that there is no elevated tract between the Damoodah and Roopnarain, so much the better, then the waters will flow off so much more freely, and do no mischief, and cannot form a stagnant marsh in the interior, and there will be no banishment from their houses for the natives, as they will soon secure their villages from inundation, as they have done in other places; nor will any remission of revenue be required, as the waters will rise so gradually, and be so shallow with so little current, that no mischief will occur to their crops. There can be no possible difference between the floods of the Damoodah and the floods of the Morhur, Poonpoon, Fulgoo and Soane, (which is sometimes added to them, though it was not in 1850,) except that these rivers united are much larger than the Damoodah, and yet do no real injury to the country.

I think these observations will prove: first, that if the bunds were abandoned, that we should have every reason to anticipate the same results from inundations in this part of the country as occur in the Gya district, in Rungpore from the Coosy, and in Assam, and all other districts where the rivers are unbunded, secondly, that if in the case of the Damoodah, only the left bank bunds are kept up, that the waters of this river will never breach the bunds, and inundate the country, as they will have an

ample outlet on the right bank, which will not suffer in consequence, whilst the zemindars will be saved a large outlay annually, and lastly, that if the bunds are kept up as proposed on both sides, that the danger of breaches, and the consequent mischief and loss will be continued, whilst the deposit of sand in the bed of the Damoodah will be an object of indifference, the river never having been navigable, and that it is very probable that the rise in its bed will be very trifling, and very unequal, and that from the great slope of the upper part, any temporary obstruction caused by the rise of the bed would be corrected by the accumulation of water in the upper parts until its body was able to sweep them away. The probable cost of the first would be trifling, of the second not great, as so much has already been done on the left bank, whilst that of the third would, I fear, be so enormous, that even if extended over several years as it would be, (it being impossible from their extent to construct them at once,) both Government and the zemindars would object to the outlay, at any rate, if this is disputed, let us have an estimate of the work to enable us to decide this point.

E GARSTIN

1*st April* 1853

MINUTE BY LIEUT-COL. MACTIER.

The question of the abandonment of the embankments of Bengal is not before the Board, and the necessity for their retention appears from the measures adopted in the recommendation of this Board to be fully recognized by Government, and what we have now to consider is, how the country can best be protected from the injurious effects of the annually recurring floods of the Damoodah, whether by embankments *alone* throughout its entire course, as suggested by the Superintending Engineer in his Report now before us, by the abandonment of these works in the right bank of the river leaving the waters to spread all over the outer districts lying between it and the Roopnarain, or as it is called there, the Dalkissore, or by a combined system of embankment and drainage.

If embankments could be so constructed as not to be liable to erosion, the Superintending Engineer's project might be feasible, but knowing as

we do that the soil through which the course of this river passes, is not of a quality to render this possible, I do not think it can be recommended.

With regard to the abandonment of the bunds in the right bank originally suggested for the consideration of the Board by Lieutenant Beadle, adopted by the majority, Colonels Cheape and Hawkins, and advocated by Major Baker, the Government Consulting Engineer, it appears to me that unless it can be shown that injury to property would not be the consequence, or that Government is prepared to grant liberal compensation to parties whose property may be injured or destroyed by the measure, it cannot, I think, with justice be adopted.

I would therefore, when submitting Lieut.-Col. Goodwyn's Report to Government, recommend that the bunds in both banks of the Damoodah be constructed of efficient Section, and with the view to relieve the waters as much as possible, and avoid expenditure by increasing their dimensions, that advantage be taken of the natural outlets to lead off the surplus waters into the Hooghly and Roopnarain. The Canna Nuddee, one of these, notwithstanding the earnest solicitation of the inhabitants of the district through which it passes, was blocked up last year by order of the majority of the Board, so that not a drop of water passes that way whether the Board had any right to obstruct this passage, I know not, but be this as it may, I would suggest to Government that the bund be removed and the escape of the surplus waters be encouraged by the excavation of the channel, as prayed for by the people and recommended by Major Kennedy, the late Consulting Engineer, and the Stipendiary Member of the Military Board. The Nullah branching off from the Damoodah opposite Selimpore to within a very few miles of the Dalkissore, suggests the practicability of letting off a portion of the floods at this point, but the lateness of the season and the impenetrable jungle have prevented 2nd Lieutenant Stewart, who was employed to examine the locality, furnishing the Board with the information called for.

This question, with others of equal importance, will be taken up and reported on by the Superintendent of Embankments, who will carry out whatever system may be resolved on.

(Signed) W. MACTIER.

8th June 1853.

No 12733

FROM THE MILITARY BOARD,

TO THE MOST NOBLE JAMES ANDREW,

MARQUIS OF DALHOUSIE,
Governor of Bengal,

REVENUE DEPARTMENT.

Fort William, 15th February, 1854.

MY LORD,

Department Public Works

Agreeably to the promise contained in the 8th paragraph of our letter, No. 11145, of the 16th ultimo, we have the honor to submit copy of a letter, No. 5162, of the 23rd January 1854, from Lieut.-Colonel H. Goodwyn, Superintending Engineer, South-Eastern Provinces, containing his remarks upon the memorandum drawn up by Captain C. H Dickens, Officiating 2nd Assistant Secretary, Military Board, and his further observations upon the floods of the Damoodah, and measures he would recommend for the protection of the country on the right bank of that river, and accompanied by a sketch Map (in original,) showing the course of the floods

2nd. Our Board will not increase the bulk of the correspondence already before Government by detailing the contents of this letter, but proceed at once to make a few brief remarks.

3rd. Colonel Goodwyn is not correct in his supposition, in the 7th paragraph, that the distances of points on the river above and below Burdwan, as marked on the Longitudinal Sections, are taken in the most direct practicable line. They are measured along the centre of the channel, following its sinuosities.

4th. The difference between the declivity of the river as taken by the fall of the bed, and as taken by the fall of the surface, referred to in the 10th paragraph, amounts to less than $\frac{1}{6}$th of a foot per mile on the average, which makes no such difference in the amount of the calculated discharge as to at all affect the question at issue.

5th. We quite agree with Colonel Goodwyn that if the Damoodah embankments are to be maintained, an efficient establishment should be provided for the purpose, and that this establishment should be guided by a proper Code of regulations and professional instructions.

6th. We are also perfectly agreed that protection from the floods should be afforded to the right bank of the Damoodah, and as to the extreme desirableness, or rather necessity, for preventing the ravages described in Colonel Goodwyn's report, *if possible* The possibility of affording this protection is the point now under discussion, and when it has been decided by authority what system is the best to adopt in order to secure the greatest advantages to the country, the works should be carried on with the principles of that system in view, and (as we have before recommended,) under the superintendence of an Officer who shall have no other duties to attend to.

7th. We beg to draw attention to Colonel Goodwyn's estimate for placing the bunds on the right bank in an efficient state, the cost of which he reckons at Rupees 3,63,750.

8th. We have nothing further to add to the opinions expressed in our former communication.

We have the honor to be,

My Lord,

Your Lordship's most obedient servants,

E. GARSTIN, *Colonel.*

W. MACTIER, *Lieut.-Colonel.*

No 5162.

FROM LIEUT.-COL. H GOODWYN,
Superintending Engineer, S E Provinces,

TO LIEUTENANT J. P. BEADLE,
Officiating Secretary, Military Board

CALCUTTA, 23RD JANUARY 1854.

SIR,

Having perused the memorandum on the Damoodah Embankments drawn up by Lieutenant Dickens and acknowledged in my No. 4638, of 28th December 1853, I have the honor to avail myself of the permission in the 2nd para. of your No. 10260, of 24th ultimo, to offer the following supplementary remarks.

2nd. The conclusion arrived at in the memorandum, that there is a necessity for relieving the river-bed by some means, and that the best method is that of abandoning the protection on the right bank, seems to be derived from an assumption of the incapacity of the various lower reaches of the river-bed to pass the volume of water flowing from the upper during floods.

3rd. I will premise my remarks by stating that the breaches which occurred in and since 1840 are scarcely to be attributable to the want of power to resist the flood water, for it is well known how inefficient the construction of the embankments has been even up to the last year or two, and therefore it can scarcely be a fair deduction, that though the area of channel was less, the flood discharge could not take place, for the velocity must have effected the discharge, and the breaches would doubtless have occurred with a diminished flood power.

4th. The case of the Eastern Jumna Canal alluded to in para. 38, is not applicable to the Damoodah. The Canal is an artificial channel cut through soils varying in density irregularly, and as it appears, the "light sandy soil in its upper parts," now the reverse is the case in the Damoodah, for the lighter and finer sands are in the lower reaches, increasing in

coarseness as the river is ascended, again, the channel of the Canal has an equable flow of water throughout the year, or, if difference of volume occurs, it is generated gradually, whereas the river is suddenly affected by violent floods, lasting only for short periods, which floods are the true governors of the river's state, and laws to regulate which are only to be framed from the effects on the bed and bank of those periods

5th The remark regarding surface drainage in the 39th para is only applicable to the river above Burdwan, for from its elevated position no drainage into its bed occurs between that spot and Omptah, and thus it is that the heights of the flood levels are so much greater in the upper reaches, for, the fall being greater the nearer the source, the effects are more violent there, the torrent having assumed a more equable power below, and varying in velocity with reference to the area of channel

6th With reference to para 56, it is to be remarked that the embankments are more stable than the bed or banks of the river I am not alluding to the former constructions, but to works properly consolidated, rammed and turfed, as they ought to be, but which neither bed or banks are, and the Section in para 10 of my report, No 4005, of 10th February 1853, will show that there is more than quadruple the amount of density in the resisting mass of the embankment over that of the water opposed to it, even in flood, *vide* also para (22) The banks of the river, too, when properly sloped off and artificially coated and turfed, resist well the floods, and force the necessary vertical scour as experience has proved

7th Referring to the longitudinal Section at para. 88, the distances, marked as "below Burdwan," have reference to the most direct practicable line between any two points, perhaps the line of the retired embankments, which has been drawn as straight as possible, but, in furnishing data for the calculation of areas, the windings of the channel play an important part in the facility afforded to the passage of floods. The sinuosities between VI and VII are great, and thereby considerably lengthen the channel, and afford, by means of length, an area of discharge more conformable to the wider reaches above, for both length and breadth constitute the real basin of the flood, extra width being required above where the violence is greatest (as noted in para. 5), and extra length forming an element in the basin to contain, under modified circumstances, the volume that was passed above through less length but greater width This appears to be a provision of nature, who apportions the widths of the basins of rivers to their lengths, and both to the volume, which is contained in a longer

channel as its power is decreased in its progress from above. Under this view of the case, which is confirmed by extant authors, I would submit with reference to para. 96 that I had studied the subject of the capacity of discharge, but with reference to the remarks I have just made

8th. Whether, with reference to para. 168, there be no other remedy for the disastrous floods than the abandonment of the right bank embankments is a question the solution of which may possibly be determined on the merits of the greatest amount of probabilities likely to affect the success of either one scheme or another, but, as the conclusions have all been drawn from the channels of the river above the influence of the tides, I would ask whether there is not as great a probability of passing a certain volume in some of the lower reaches above Omptah, if embanked on both sides, as there is below, where the necessity for retaining both sides is admitted to keep out salt water, and where the area of discharge is scarcely greater, and where during the flood duration, the incoming tide offers no opposition to the powerful ebb?

9th. Water moves down an inclined plane on the principle of falling bodies, with an accelerated velocity, to which of course there are limits set by nature in the admirable pool and stream system alluded to in part III of my report, No 4005, to the above principle is attributed the primary action of water descending from a higher to a lower level, which action is *vertical*, and though from the formation of river courses and beds there is alternate *vertical* and lateral action, yet the latter is referable to the original action on the bottom, the lateral action taking place when by diversion, or some obstacle, the vertical action is hindered, for it is plainly visible that only if the current is impeded in one direction will it find passage by another

10th. In regard to the remarks in paras 93 and 94, there is a very just rule laid down by the Italian Engineers, that "the greater the volume of water, the less is the slope of the bed," but also "the greater the volume of water, the greater the slope of the surface," and it is for this reason that the slope of the surface governs the *motion* of the discharge rather than the slope of the bed. The gauge piles during the last season of rains showed the flood level at Culna to be 25 feet above the river bed, whilst *the levels of the same flood at Omptah and Musraka were, respectively,* 19′ 8″ and 17 feet, so that there is a greater fall of surface than of bed, the heights having been measured from the bed. From the above therefore, no fear of silting up or deposit can be feared, even where the slope of

bed is diminished, for with diminished slope there is the larger volume, and with the larger volume the greater slope of surface which produces the requisite increase of velocity to carry off the matter held in solution, and moreover with extra velocity is produced the greater vertical action which prevents lateral erosion on the banks or embankments, nor would their height require to be increased above the standard at present laid down.

11th A report on the Damoodah Embankments published as No XII. of "Selections from the Records of the Bengal Government," having been alluded to more than once in the memorandum under acknowledgment, some remarks on its contents seem to be appropriate here, though I regret not having seen it at an earlier period, that my report of February last might have had reference thereto.

12th In the above pamphlet much is written and commented on regarding the state of the embankments and their *effects*, though but little has been advanced touching the *causes* which have hitherto led to the want of confidence in the works executed They are these

In the first place there has not yet been any organized system for either the construction of embankments or their maintenance, no code of professionally practical instructions laid down, based on experience, by which either a young Officer or Overseer could be guided. The Military Board, in a letter, No 7838, of 30th January 1849, issued an order relative to the mode of forming embankments in concave layers, and consolidating them, being a reiteration of an order, No. 6601, of 1st December 1848, previous, however, to this, no positive guiding orders have been placed in the hands of the Executive Department of such value as experience had taught, to ensure embankments being either efficiently sectioned, properly aligned, or adequately supplied with sluices and the means of drainage.

Secondly—The principle feature in the superintendence was to obtain the lowest possible rate everywhere, and the constant litigation that ensued between the protests of the Executive as to the impossibility of doing the very best work at the lowest price and the stringent orders for the exaction of so minute a standard, cause as a matter of course inferior work, merely as self-protection against the consequences of pecuniary ruin.

Thirdly.—The nature of the subordinate establishment was and is one of the greatest drawbacks to efficient work, but few of the Overseers have received an education that fits them for embankment duties, for it cannot be denied that where the precise height of the flood rise is an

essential point to ascertain throughout the entire lines, the art of levelling should be known to the person entrusted with the work, for it is physically impossible that the Executive Engineer can attend personally to the whole of the embankments, scattered over some 900 or 1000 square miles, each season. Some slight acquaintance with surveying too they should have, yet I know not at this moment of four subordinates, in the whole of the embankment divisions between Burdwan and Cuttack, who can either survey or level The consequence is that embankments are made below the efficient level which has been more apparent since the establishment of flood gauges which I ordered to be erected for the first time last year. Of the Darogahs and Mohurirs, I cannot write in sufficiently deprecatory terms, their sole object is plunder, both of Government money and the earnings of the workmen. Dishonesty and utter corruption are the plague spots which mark these men throughout, and they are most potent hindrances to good work of any kind that could have been introduced to mar the most energetic attempts at improvement I have reported this matter and submitted suggestions for remedy, *vide* my letters, Nos 1725 and 1632, of the 26th August 1852, and 3rd July 1853, to the Military Board

The *fourth* and last cause of inefficiency and disaster is the entire want of legal protection to the embankments The villagers, urged by zemindars, can cut embankments without fear of detection, and commit deeds of atrocity more fatal in their effects than arson, the plough may cut up the slopes, and the cattle devour the turf (put on at great cost) with perfect impunity

13th Such are the causes which require immediate remedy before the science of the Engineer can work reform proportionate to the interests or expenditure There are besides some other considerations necessary to aid in the good work, *viz*, that proper surveys on a tolerable and uniform scale be made of the embankment divisions and the rivers, which should be instituted in joint concurrence with the Engineering and Revenue Departments, and the extent of individual charges should be circumscribed within more practical limits of observation and control.

14th. There is no want of experience in embanking in the country, but there is a want of time on the part of those possessing it to embody, condense, and arrange for the benefit of the department at large, the result of their experience, at present it can only be, as it is, doled out in a succession

Para 5, Note by Mr Ricketts

of Orders and Circulars, at irregular intervals, such exist now, but much more might and should be added thereto, to render them as serviceable as they ought to be.

15th. On the right bank the soil is the same as on the left, the proportion of population per square mile (where not rendered desolate by the floods) is the same, the food required for the people is the same and the same produce is required for the same markets. It is true there are the Grand Trunk Road and the Railway on the left bank, but there is on the right, one of the principal thoroughfares of Bengal, *viz*, from Calcuta *vid* Midnapore to Cuttack, &c, which is endangered every year by the Damoodah floods, and has within the last three years been twice seriously breached. In 1850, when the flood poured over the country broke through Boxee Bund, and swept away a mile of the Road East of the Roopnaram, and this year, when one flood from Kistopore simultaneously with one down the Damoodah Khal rushed resistlessly over the country to the Roopnaram, which they together entered at Rogonutpore, and the Boxee Khal at Mancoor caused that river to overflow and breached the Road between it and the Cossye A sketch of the course of these floods is annexed. of the utter desolation and ruin which the country presents, no picture can be drawn It should be witnessed, as it was by the Collector, Lieutenant De Bourbel, and me, on the 8th December, to enable opinion to be formed, and which would be a strong advocate for protection to the hundreds of houseless ruined human creatures With my Nos 4245½ and 4513, of the 6th and 9th December 1853, I forwarded petitions, praying for the restitution of these embankments.

See Mr Drummond, No 20 of 22nd January 1852, paras 27, 28
Mr Rickett's Note para 19
Military Board's, No 2692, of 6th July 1852, para 14

16th. The expression in the 28th para. of Mr Drummond's letter of 22nd January, that the "feeling of the country, as far as he was able to "ascertain, was decidedly and almost universally in favor" of the abandonment of the right bank embankments seems to be completely changed, (if he ascertained "far,") for I traversed the whole line with the Collector Mr. Ward, during the early part of December, who can certify to the fact that without one exception, Zemindars, Putneedars and Ryots made anxious solicitations for the formation of these embankments, and the petitions alluded to above likewise corroborate the same.

17th. The Rajah of Burdwan, when called on to state to Mr Ward (the Collector) last May, whether he objected to the abandonment of the

right embankments, simply objected to the shortness of the time for reply and expressed no decided objection, since which time I have ascertained from the Collector that the principal part of the land has been let in Putnee Talook, the nature of which holding precludes any intimate knowledge of the state of the management of the estates, on the part of the Zemindar, as he has transferred his interest to the Putneedar Hence the Rajah's reply above. I find on the land where the flood ravaged the country last rains, West of Kistopore, that at the last half-yearly sale of Putnee Talooks Kistopore (the Putnee Jumma of which was 1,200 per annum) was sold for arrears of Revenue *to the Rajah* (the Zemindar) for Rupees 10! It having thus come into the hands of the Land owner, he will not be able to realize more than 100, if so much The Rajah therefore now, feeling the necessity to be pressing, is anxious as all the rest for the protection to his estates, lest they fall into his hands barren as this one.

18th. Again, there are two young Zemindars of Sreekistopore by Culna, on the right bank, who have been partly educated at Hooghly, and who came to us on our arrival there (7th instant) and told us of their anxiety to go again to the college to complete their education, but that they were unable, having suffered ruinous losses from the floods of the last two or three seasons, which devastated their lands and depopulated their villages Such are some of the strong facts bearing down the scale of protection. Moreover, the inhabitants state that the only reason, why the few villagers now remain on the spots rendered desolate is, that they have tenanted the land from their births, that their ancestors are buried there, and rather than quit the spots thus rendered sacred, they will content themselves with but one crop a year, a precarious existence enough. This needs no comment. The area laid waste is about 160 square miles

Mr Rickett's Note, para 10

19th Mr. Ricketts in his 10th paragraph likens the Damoodah under flood to a basin with a hole in the bottom receiving a greater influx from a cock than can be passed out by the hole. The simile does not hold good. It is not that there is not sufficient area of exit for the waters of the entire basin, but that violent floods come down so rapidly that they execute their mission of ruin in the higher reaches before they arrive at the lower, and where they have somewhat subsided. Wave over wave comes rolling down with impetuous force, and the waters accumulate

rapidly, as if driven from their mountain bed by some storm spirit. The total rise gained by these torrents is from 18 to 22 feet in half that number of hours, and is pouring itself over the right bank at Kistopore (by no means a narrow channel) before it is heard of at Omptah. It must be borne in mind, too, that these flood waves are not laden with silt for fertilizing, but with sand scoured up from the bed and laid on the land to its destruction. I may here remark on a prevalent error which supposes the floods to be beneficial to the land by the deposit of alluvium, such however is not the case, it is only in the cases of equable rises in the river *without a flood torrent*, which occur during the season when by spreading quietly over the land, the fertilizing deposit might be made, but the torrent flood bears desolating sand in its train, first ploughing up the yielding surface and then sowing it with ruin

Mr Rickett's Note, para 19

20th This brings me to the consideration of the retired lines, several of which have, I regret to observe, been made without a due recognition of the two-fold duties which embankments ought to be made to perform, the one protective to the country, the other as tending to improve the river. The latter being entirely lost sight of altogether in lines so retired as some on the left bank constructed in 1850-51, whilst inefficient protection is afforded at the sacrifice of thousands of beegahs of land, and many unprotected villages The absence of proper levels has blinded the Executive Engineer as to the height to which these ought to be carried, the lines behind Mohunpore and Bangamarra were overtopped and breached in several places, having been placed more than a mile inland and with a crest little higher than the marginal line, the fall of country being considerable.

Mr Drummond, No 20, of 22nd January 1852, paras 11, 13, 14, 17

Any good effect of these retired lines is more imaginary than real, for when the fact of the practicability of passing the flood waters down is shown, what remains of good?—that a greater quantity of land is fertilized by deposit? Not so, for in some of the positions where the lines are so thrown back, there are intervening villages, numerous tanks, groves of trees, &c., which arrest the silt, so that it seldom reaches far beyond the margin, whilst as that margin rises, the waters are pent in at the base of the embankment forming a marsh, and keeping its base constantly moist and inducing settlement. Thus the entire crops of one-half the year cannot be obtained, whilst both the Collector and I were told at Bangamarra

Mr Drummond, paras 18, 19

that the people could no longer remain in the villages, thus abandoned to inundation, but must quit that part of the country, some of the villages being a half and others three quarters of a mile from the river.

21st. Much has been written about the difference of the value of land outside and inside the embankments, but the matter to be determined is not whether the land outside or inside is most valuable, but whether the land shall or shall not be rendered, by a sand laden flood, of no value at all. It is not a question whether a theory shall be supported, but whether the truth shall be sought for

Mr Drummond, paras 3 to 10
Mr Rickett's Note, para. 13

I may state that on my first visit to the embankments in 1847, I did not recognize the two-fold value of the embankments alluded to in the last paragraph, and partly advocated the axiom of the shortest distance between two points, and the formation of straight lines not having reference to the river, but having since studied the subject I became aware of the previously erroneous idea, and am borne out by professionally Hydraulic Engineers, that the state of the river banks requires great attention, and that the permanence of the embankments depends as much on the protection of their existence by forcing a vertical action of the water to preserve the banks, as by actual solidity of construction Since my return to this superintendency 1852, I have in a series of Circulars laid down nearly a complete guide for the construction and maintenance of these works, and I have been gratified that during the last season much good has been effected There is no doubt but that much remains to be done, and when the causes of want of confidence referred to in the 12th paragraph are removed, I have little doubt of complete success on both sides

22nd That an embankment can be made efficient and able to resist the heaviest floods, mark the following: water may be taken as weighing 65 lbs per cubic foot, and the force exercised by a gale of wind is computed at 35 lbs per foot, which may be said to be that of the pressure of flood water Thus in the annexed Section* (which is that of a line on left bank) and allowing the pressure to be exerted at an angle of 45° there is an area of 360 feet of water, the pressure of which, as above, is equal to 23,400 lbs., which has to be resisted by an embankment, the weight of a cubic foot of whose material is 148 lbs, or giving an entire mass of 1,22,840 lbs., so that the resistance is about five times the amount of pressure, which only lasts during the period of the passing flood.

* See page 15